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ABSTRACT

This book provides job descriptions and discusses career opportunities in various fields of the biological sciences. These fields include: (1) biotechnology, genetics, biomedical engineering, microbiology, mycology, systematic biology, marine and aquatic biology, botany, plant physiology, plant pathology, ecology, and wildlife biology; (2) the biomedical sciences (physiology, biophysics, biochemistry, pharmacology, immunology, and pathology); and (3) applied biology (forestry and agriculture). Opportunities as laboratory assistants, technicians, technologists, and technical writers are also considered. Additional information provided includes what it is like to be a biologist (examining personal attributes of biologists, women and minorities in biology, demand for biologists, and the tangible/intangible rewards of a career in biology); education of a biologist (considering high school subjects, college requirements, graduate study, and financial aspects); employment of biologists (focusing on employment in educational institutions, governmental agencies, industry, independent research laboratories, botanical gardens and arboretums, zoos, museums of natural history, volunteer services, and self-employment situations); and information on finding a job (discussing college placement bureaus, periodicals, professional associations, and personal contacts). A list of selected sources to obtain further information is appended. (JN)

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# Opportunities in
# Biological Sciences

Charles A. Winter

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# OPPORTUNITIES IN BIOLOGICAL SCIENCES

**Charles A. Winter**

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# ABOUT THE AUTHOR

Dr. Charles A. Winter is a former research worker in pharmacology at the Merck Institute for Therapeutic Research. At the time of his retirement, he accepted appointment as Professor of Pharmacology at Woman's Medical College in Philadelphia, and also retained a consultantship with his former employer.

After receiving the A.B. degree in biology at Southwestern College, Winfield, Kansas, he studied zoology at the University of California and at Johns Hopkins. He then accepted appointment as Instructor of Biology at the University of Buffalo. While teaching at Buffalo, he took graduate work in physiology, receiving his Ph.D. He subsequently taught physiology at the University of Iowa and University of Oklahoma, before devoting full time to research at Merck Institute.

Dr. Winter is the author of more than a hundred scientific publications, and has lectured at many international meetings in the U.S.A. and abroad. His memberships in scientific societies have included the American Association for the Advancement of Science, the New York Academy of Sciences, the Royal Society of Medicine in London, the American Physiological Society, the American Society for Pharmacology and Experimental Therapeutics, and others. He is a former Chairman of the Gordon Research Conference on Medicinal Chemistry.

Dr. Winter was called out of retirement to serve as Acting Director of Research in Labortoires Chibret in France. Upon his return from France, he settled in the state of Washington to be with his family, where he received appointment as Consultant to the Department of Pharmacology at the University of Washington and Visiting Professor in the Department of Biological Sciences at the University of California in Santa Barbara.

# FOREWORD

Choosing a career is one of life's most difficult decisions. Some people's interests immediately suggest a specific goal; for many the choice can be made only gradually, as new ideas and experiences are encountered.

Biology is the study of all forms of life: how they interact, exist, reproduce. It is a fascinating field that can excite and satisfy your curiosity. Research in biological science can involve you in discovery of how the structure of the brain affects thought and reaction, or how the chemicals of the body affect the way the brain thinks and reacts. Applied work in biology and engineering could give you a role in the creation of artificial sight or hearing.

Think of biology as a starting point for a career in such fields as optometry, farming, veterinary medicine, nutrition, or occupational therapy. There is new work being done in bioethics and philosophy of science. Many types of sales careers require a biological background. Biology teachers have the opportunity to pass on their excitement, knowledge, and curiosity to students, to participate in research, and maintain an interest in all facets of biology.

The National Science Teachers Association has made a commitment to science, and a commitment to help give students a background from which to make decisions. We hope that this book will help you evaluate your personality and needs, and compare them with those of others who have chosen a career in the biological sciences.

Walter S. Smith, Chairman
NSTA Task Force for Defining Excellence in Science Teaching and Career Awareness

Shirley L. Watt
NSTA Publications Staff

# DEDICATION

*To Greta*

# PREFACE

Many of the things we value in life remain constant and unchanging, but those who write on biological topics know that their writings soon become out of date. So it has been with *Opportunities in Biological Sciences*. The fundamentals of biology do not change, but new facts emerge at a dizzying pace. Each answer to a question raises more questions. New discoveries bring new employment opportunities, even new kinds of careers. Factors outside of science, such as economics, politics, and population trends, also affect the demand for trained people. It has therefore become essential that if this book is to fulfill its function of giving useful information to young people seeking career guidance, it must be updated from time to time. It is the hope of the author that preparation of this third edition will fulfill the need and that those seeking information on careers in the fascinating world of bioscience will find it useful.

C.A.W.
Redmond, Washington



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Biologists with the U.S. Soil Conservation Service, above, in ranch planning. Photo: Donald E. Schuhart. Below, U.S. Department of Energy biologist works with massive experiments involving hundreds of thousands of mice over fifty generations to study effects of radiation on mammals. Photo: Frank Hoffman.

CHAPTER 1

# INTRODUCTION

## CHOOSING A CAREER

Although this is a book about careers in biological sciences, it is not intended as propaganda singing the praises of biology. Rather, it is my intention to present in a realistic manner the choices available in the biosciences so that the reader will have the information needed to make an intelligent choice.

Changes are occurring so rapidly in our culture that it is a challenge to find an occupation that will not become obsolete before the end of one's productive years. The career you choose should be in a field you enjoy, and there should be a reasonable prospect of employment when you are ready. You will need to know what sort of details will occupy your attention, both while you are preparing for the work and during your actual working time. The monetary compensation should be adequate for a reasonable life, but such rewards should not be the sole reason for your choice.

If you are trained in biology, you will find many career choices awaiting you. Biology is not a single science, but a collection of sciences, all having the common element of dealing with some aspect of living creatures. Choosing a biological career is one of the surest ways of being able to participate in helping to solve the problems of preserving the environment, increasing food supply and improving health care.

In the mid 1970s, the Scientific Manpower Commission predicted that there would be a rising trend well into the 1980s in the number of graduates with a baccalaureate degree in biology. Although the fulfillment



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of this prediction has been influenced by a number of factors, there is much evidence that the demand for young people trained in biology will continue to be strong. The economic recession of the late 1970s and early 1980s led to a reduction in demand for trained people in many fields, but the marketability of biological skills held up better than many others. According to a report by the National Science Foundation, there was actually an increase in employment of those holding doctorate degrees in science and engineering during this period. Biological sciences was the only field in which there was a steady increase in the number of advanced degrees awarded. Although educational institutions account for the largest number of scientists and engineers employed, the largest percentage increase was in industrial research and development laboratories. For several decades these areas have been expanding employment of scientifically trained personnel at a rate of more than 5% a year. Even that rate was considerably exceeded during the early 1980s. Growth was spurred by important breakthroughs in biology, especially genetic engineering, according to reports by the National Research Council and the National Science Foundation.

Such reports focus their attention on fully trained professionals with advanced degrees. It is worth mentioning that for each such position, from three to five technical assistants are required. There is a place for those with a wide range of skill and experience. The Cam Report on career movement in 1983 listed a number of new careers, a high proportion of which require a biological background. It was predicted that we may see a whole new set of technologies, with systems to support them.

The present and future of biology, as in all lines of endeavor, are built upon the foundations of the past. It is therefore appropriate that before we go into greater detail of biological careers, we take a brief look at some historical landmarks.

## BIOLOGY — PAST, PRESENT AND FUTURE

### The Ancients

Like most other things in our Western culture, biology can trace its origins back to the ancient Greeks and Romans. In the fourth century B.C., Aristotle classified plants and animals, and his pupil, Theophrastus, wrote the first botany book. Some of their notions seem strange to us.

Aristotle's theory that the same kinds of animals would be found on the same parallel of latitude around the world so misled Columbus that he was disappointed at not finding elephants in Haiti. Hippocrates is still revered for laying the foundations of medical science. In the first century A.D., Seneca made observations aided by magnifying glasses consisting of globules filled with water.

**Biology Awakens After The Renaissance**

The biological lore accumulated by the ancients was forgotten in Europe for more than a thousand years. The ancient records kept alive by Arab and Jewish scholars in the Middle East were brought back by returning Crusaders. Even after the Renaissance, progress was very slow by modern standards. During the next three hundred years, only a few names stand out—Vesalius, the "father of anatomy," William Harvey, who discovered the circulation of the blood, and Robert Hooke, who introduced the concept of "cells" as units of biological structure. Seneca's crude ancestor to the microscope was not improved upon until the late seventeenth century when a Dutchman, Anton van Leeuwenhoek, devised the first microscope and discovered the existence of animals and bacteria too small to be seen with the unaided eye.

The eighteenth century witnessed several advances in what we would now call biochemistry. Priestley, an Englishman, discovered that green plants give off oxygen, while two Frenchmen, Lavoisier and Laplace, pointed out that respiration of animals is a form of combustion, like the burning of wood. The great Swedish naturalist, Carl von Linne, commonly known by the Latin form of his name, Carolus Linnaeus, devised the scientific method of classifying and naming plants and animals which is in use to this day.

**The Nineteenth Century—The Modern Age Arrives**

The immense changes in our way of life which came during the nineteenth century also saw revolutionary new ideas in biology. All living organisms are made up of cells, theorized two Germans, Schleiden and Schwann. Another German, Liebig, discovered that plants synthetize organic compounds from carbon dioxide of the atmosphere and nitrogen from the soil. Louis Pasteur, of France, pioneered in microbiology and proved that living organisms do not arise spontaneously from non-living

matter—all life comes from life. His discoveries and those of the German bacteriologist, Robert Koch, paved the way for many advances in the treatment of disease, including aseptic surgery. The principles of heredity were also discovered during the nineteenth century by an Austrian monk, Gregor Mendel, though his work lay forgotten until the beginning of the twentieth century.

No event in biological science in the nineteenth century had greater impact than the publication in 1859 of Charles Darwin's *The Origin of Species*, setting forth the theory that species of animals and plants gradually change over long periods of time because of natural selection. The idea that species could be transformed was not entirely new. Anaximander in the sixth century B.C. had proposed that one species could evolve into another. More than a century before Darwin's publication, the French naturalist Buffon, asserted that species could change. Charles Darwin's grandfather, Erasmus Darwin, thought that species could be transformed by environmental influences. The Frenchman, Lamarck, had also emphasized the fundamental unity of all life and the capacity of species to vary.

Even in the idea that natural selection brought about evolutionary changes, Darwin was not alone. Alfred Russel Wallace came to identical conclusions at the same time; indeed, the initial public disclosure of the theory was in a joint presentation of papers by Darwin and Wallace to the Linnaean Society in London. The subsequent publications in greater detail by Darwin, including *The Origin of Species* and *The Descent of Man*, have led to the association of his name, rather than Wallace's, with the evolution theory.

### The Twentieth Century—And Beyond

Developments in the present century have shown that evolutionary changes within a species are essentially changes in the frequency of the occurrence of specific "genes" within a population. Genes, the units of heredity, interact with each other and with the environment to produce the manifestations of inherited characteristics. The gene theory was formulated by Thomas Hunt Morgan early in this century. More recently, details of the structure of genes—deoxyribonucleic acid (DNA)—have been worked out by two biochemists, an American and an Englishman, Watson and Crick. So much has been learned about how to handle DNA that some fear this new knowledge gives biologists altogether too much potential

power to produce whole new species of dangerous disease-producing bacteria and perhaps other monstrous forms, or maybe even control heredity in humans. Biologists working in this field, aware of the potentialities, have met and agreed upon certain rules aimed at guiding research along lines that will not be harmful to mankind.

Examples of biological discoveries will be given throughout this book. Exciting new findings are lying in wait for those with prepared minds. Many will be made by people now barely beginning the study of bioscience and possibly by some who have not yet made up their minds whether they really want to be biologists. Perhaps this book will help you make that decision.

## WHAT IS SCIENCE?

One frequently hears a biologist—or some other scientist—marvel at his good luck in getting paid for something which is so much fun to do that he would do it even if he no longer had to work for a living. Science is a way of life, and scientists in general are happy, well-adjusted people. Motivation for following science as a career comes from within, and for many the urge to pursue science is as strong as that toward a religious calling. And like the religious calling, the chief attraction to science is neither the monetary reward nor the promise of easy living. The realization that you can leave the world richer than you found it will be part of your reward as a scientist.

There is confusion in the minds of many people as to the distinction between science on the one hand and technology and invention on the other. The confusion is understandable. We are accustomed to frequent changes in our way of life brought about by new discoveries and inventions. New drugs help to control diseases; new varieties of plants and animals increase agricultural yields; new processing methods bring us new foods (though not always improving on taste or nutritional value); transportation speeds up until we can move through the air faster than sound can travel. Such innovations are often regarded as "advances of science," and many people believe that invention is the object of science. That is not really true, even though the inventions would not be possible without the scientific discoveries upon which they are based. Many very fine inventors are not scientists at all; while most scientists have never invented anything of practical value.

There is, then, a distinction between science and technology. Science seeks to understand the forces of nature, and the scientist's reward is the joy of discovery and a contribution knowledge. Technology on the other hand puts this knowledge to practical use. In some instances the distinction becomes somewhat subtle. We sometimes hear about *pure* or *basic* research as distinguished from *applied* research, and there are arguments about whether a scientifically trained person is truly a scientist if he uses his talents for making discoveries which he hopes will lead to a practical result. Basic investigations often lead to practical results— sometimes years after the basic discovery has been made.

When the British biologist, Alexander Fleming, discovered that a substance produced by the bread mold *Penicillium* could kill bacteria, he was engaged in basic research, but in the end his inquiry led to the important practical result of the isolation of penicillin. This work ushered in a whole new era in medicine—the antibiotic era. Penicillin would not have become a useful product, however, without a large amount of practical research and the application of skilled technology. Hence, science and technology often work closely together, and enlightened industrial leaders have dedicated more and more of their funds to basic science. Today, much important basic work in the life sciences as well as in other sciences is performed in the laboratories of industry.

The immediate aim of science, generally speaking, is not usefulness, any more than is a painting or a musical composition; but the fruits of science, like those of art or music, can enrich our lives. Some of the things that science has to contribute are the spirit of inquiry, the enthusiasm for exploration, the habit of rigorous analysis, the inquisitive outlook, the quest for truth, and the willingness to discard pet notions once they are found to be mistaken. Ideally, the scientist exhibits total objectivity and scrupulous integrity. As the biologist Konrad Lorenz has put it, "It is a good morning's exercise for a person in research to discard a pet hypothesis every day before breakfast; it helps to keep him young." Such a change of mind would be very distrubing to the average adult. Scientists are only human, and they sometimes fall short of the ideal, but from time to time one does see a published retraction of a position previously held.

Another distinguishing feature of the scientist is that he or she doesn't have to pretend to know something in the field that he doesn't know. The scientist may guess what the answer will be, and may have ideas about how to go about finding the answer; but if he doesn't know, it is not shameful to say so. A large scientific gathering was addressed by the then

ten-president of the American Association of the Advancement of Science. Regarding a difference of opinion between himself and another eminent worker in the same field, he said, "Of one thing I am quite sure; neither of us knows anything about it." Louis B. Flexner once said of his work, " . . . although I have confidence in the observations, I am far from wedded to the interpretations, which, in my opinion, badly need further work to test them."

How refreshing it would be if many people in other fields were to adopt a similar attitude! If you choose to become a scientist, you will be privileged to meet many people with such attributes, and you will be proud that you have chosen a career in science.

## WHAT IS BIOLOGY?

We have already alluded to the fact that biology is a group of sciences, rather than a single science. But no matter how the daily activities of one biologist may differ from those of another, all bioscientists are concerned one way or another with living creatures. All living things have certain properties in common, whether they be plants, or animals, or microorganisms. All require sustenance derived from materials absorbed from the environment. They all grow and develop, and all respond in predictable ways to the environment. All of them depend upon reproduction to perpetuate their kind. All of these processes are governed by natural laws which are the same for all. Biology deals with all of these things—and more.

Many of the problems of modern civilization can be solved only by the application of biological knowledge. Examples of these problems are easy to find: pollution of air, water or soil, the disposal of wastes, the effects of overpopulation and crowding, the use of drugs, the aging of the population. Improvement of the food supply and elimination of heritable diseases also are challenges to the biologist. Biology is also involved in solving problems associated with descent into the depths of the sea, and ascent to the highest mountains, and even into outer space.

You can readily appreciate, then, that biology is much more than taking specimens of plants and animals into the laboratory and looking at them and describing what you see. It may interest you at this point to take a brief look at the types of biology and the range of careers available to those trained in bioscience.

**The Scope of Biological Sciences**

The classification of biologists as botanists, zoologists, or microbiologists gives little hint of the wide variety of biological disciplines that exist. For example, the microbiologist whose primary interests make him a *bacteriologist* may perform very different duties than the *virologist.*

One kind of zoologist, the *taxonomist* or *systematist,* specializes in the identification, description, and classification of animals and determines how a given species fits into the scheme of nature. Seldom will the interests of a zoological systematist range over the whole animal kingdom; he is more likely to specialize to some extent. If, for example, he mainly studies mammals, he is a *mammologist;* if reptiles, a *herpetologist;* if insects, an *entomologist;* or fish, an *ichthyologist;* if protozoa, a *protozoologist;* and so on. Botanists and microbiologists can be systematists, too. A diminishing breed is the "generalist," a systematist whose interests range across the boundaries between plants and animals. One of the greatest of these was Linnaeus, mentioned in the preceeding section of this chapter.

Bioscientists of several categories are fascinated by the structural details of organisms-they are *anatomists* or *morphologists.* If the microscopic structure of tissues is the object of the morphologist's scrutiny, he is a *histologist.* Still more detailed study of the structure within cells makes him a *cytologist.* If this sounds like morphology is a lifeless and dull subject, the impression is far from the truth. The cytologist, for example, is keenly aware of the relationship between the structural components of a cell and cellular functions. So, cell morphology becomes a background for other branches of *cellular biology,* such as *cellular physiology* or *biochemistry.* The *molecular biologist* is preoccupied with an even more intimate examination of the ultimate mechanisms within a cell.

From this brief survey, you can see that the interests of bioscientists range all the way from a systematic examination of whole groups of plants or animals (or both) down to the level of the molecules that make up cells. But that is only the beginning! No group of plants or animals exists by itself. All groups and individuals interact with each other and with their environment, and each has a niche to fill in the scheme of nature. Its whole surroundings form an "ecosystem," so another biological science, *ecology,* is born. Patterns of behavior stimulated in each species of animal by its encounters with the world about it provide the subject matter for the science of *ethology.*

The laws governing heredity occupy the attention of the science of

Biologists at work in pharmaceutical biology experiments at Abbott Laboratories.

The laws governing heredity occupy the attention of the science of *genetics*. Geneticists may apply mathematics, anatomy, biochemistry, or a host of other disciplines in their efforts. The lines between different biological vocations are often rather poorly defined and there is much overlap. For example, if a life scientist is interested in the genetics of bacteria, is the scientist a *geneticist* or a *bacteriologist?* If the favorite subject is the embryonic development within the egg of a reptile, is the scientist an *embryologist* or a *herpetologist?* Is the botanist who writes papers on diseases of trees caused by fungi a *mycologist* (student of fungi), a *dendrologist* (expert on trees), or a *plant pathologist* (concerned with diseases of plants)? In each case, he or she is a bit of each, and can be classified according to what the primary interests are—and this can change during different stages of the scientist's career.

*Wildlife biologists* are concerned with wild animals, fish, and fowl, and *marine biologists* are fascinated by the richness of life in the sea, but either may concentrate on taxonomy, physiology, ecology, or any of several other specialties.

All biological disciplines are basic sciences, but each one also has practical applications. Thus, agriculture and forestry make wide use of plant and animal sciences. Those biosciences having important applications in health and diseases of man or other animals are commonly referred to as *biomedical sciences*. They include certain aspects of biosciences we have already mentioned, such as anatomy, physiology, biochemistry, and microbiology, as well as such disciplines as *biophysics, nutrition, pharmacology,* and *pathology*. All of these will be discussed in succeeding chapters. When the public press mentions "the advances of medical science" the reference is usually to reports of research in one or more of these life sciences.

Some of the newer biological specialties that have emerged in recent years which may expand significantly in the future include *genetic engineering* or *biotechnology,* involved in manipulations of the units of heredity (see Chapter 4); *biomedical engineering* is concerned with replacement of faulty organs of the body; *gnotobiotics* deals with breeding and growing animals in germ-tree environments; *teratology,* the study of abnormalities has become important with our increasing exposure to harmful environmental influences—teratologists are widely employed in laboratories of the chemical and drug industries; *aquaculture* is a rapidly growing technique for growing foodstuffs in water, especially high protein foods such as fish; closely related is *hydroponics,* or growing plants without soil in an aqueous medium. Some of these specialties have been around for

many years but are assuming greater and greater importance with the increase in population and decrease in available arable land. Other biological specialties which are expected to be in increasing in demand include *paramedical* personnel who assist in health care—medical technicians, physicians' assistants and others. Some of these will be discussed in a later chapter.

During a lifetime career, a bioscientist may engage in teaching, research, administration, service work, or industrial production. If you choose to become a biologist, you may specialize in one of these activities, or a combination of two or more, or you may switch from one to another at various stages of your career. Your employer may be an educational institution, governmental installation, private research foundation, zoo, botanical garden, aquarium, arboretum, natural history museum, or an astonishingly wide variety of industrial or business concerns. Few biologists find life dull.

A research biologist studies cells infected with viruses capable of causing tumors as part of a study to determine interaction of viruses and environmental carcinogens. Photo: Frank Hoffman, U.S. Department of Energy.

CHAPTER 2

# WHAT IT'S LIKE TO BE A BIOLOGIST

## WHY BE A BIOLOGIST?

If you have a curiosity about the nature of the world and about the life upon it, you have one of the main attributes for success in a biological career. If you are somewhat of an idealist, thrilled with the prospect of improving the lot of your fellow mankind, there are many areas of biology that may appeal to you. If you are of a practical turn of mind, and wish to be reasonably sure of making a living, biological careers offer a number of choices.

To some, the word *biologist* may conjure up the image of a rather shabbily-dressed, absent-minded, middle aged professor forever roaming about fields and meadows with a butterfly net in his hand or interminably peering through bird glasses. Now, it is perfectly true that collecting insects or observing wildlife is a legitimate occupation of certain kinds of biologists. One who studies insects is an *entomologist* and the specialist in birds is an *ornithologist,* but as we shall see in Chapter 4, there is a lot more to being an entomologist or an ornithologist than just watching or collecting these captivating creatures. And such observation and collection are not the exclusive domain of the professional biologist; many amateurs find these activities to be fascinating hobbies.

Experimental research, especially in the biomedical sciences, has a certain glamorous appeal, and some discussions of careers in bioscience tend to equate science and experimentation. There are, however, other scientists

who analyze and interpret an "experiment" which nature has performed. To presume that all biology is laboratory experimentation is as erroneous as the impression of some nineteenth century philosophers that science is nothing more than observation and classification. The same qualities of enthusiasm, careful analysis, quest for truth, and open-mindedness are required, whether one's daily work is laboratory experimentation, field observation, classroom teaching, routine laboratory testing, application of biology to quality control in industry, or in administration and management of biological laboratories.

Those who perform biological experiments in the laboratory must of necessity make observations on living organisms. These organisms vary in complexity all the way from bacteria to human beings themselves. The elucidation of the functions of the human body has been made possible only by observations upon the bodies of animals most nearly resembling humans; that is, the mammals. Many people misunderstand animal experimentation, and you no doubt have heard the accusations of those who depict the experimental biologist as cruel and sadistic, inflicting unnecessary pain and suffering upon the victims. These people have had no experience in experimental laboratories. After 40 years of experience in such laboratories and acquaintance with many hundreds of workers in them, I can only say that the cruel and sadistic experimenter must be a rare bird indeed—I have never met one. I do know of cases, however, in which workers unable to learn careful and sympathetic handling of animals were dismissed from their jobs. There have also been cases of some experimenters criticizing others who in their opinions were not sufficiently careful to avoid pain.

Most experimenters know what their detractors fail to appreciate; namely, that observations made under conditions of extreme stress on the part of the animal subject cannot be considered to be made under "normal" conditions, and in most instances, the results might be invalid as answers to the question under investigation. Experimental biologists have drafted a set of policies for humane treatment of animals in the laboratory, and a guide setting forth these policies has been assembled by the National Institutes of Health. It is a booklet entitled *Guide of the Care and Use of Laboratory Animals,* available for a small fee from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. A group of associations of experimental biologists has also drawn up a set of guiding principles so that experiments will be conducted " . . . with a respect for life and an appreciation of humane considerations that must be

afforded all animals." These can be obtained from: The National Society for Medical Research, 1330 Massachusetts Ave. N.W., Washington, D.C. 20005.

If you are considering a career in biology, and if experimental biology appeals to you, you need have no fear that you will be in the company of unfeeling and inhuman monsters. By and large, people with inferior mental capacity rarely succeed in obtaining advanced degrees in any academic discipline. This is surely as true in the biological sciences as in other subjects. And although an occasional person of high intelligence may have a warped attitude toward her or his fellow creatures, even a casual observer must have noted that the so-called "intellectual community" leads in urging society toward a deepening understanding of all life and a lessening of cruelty, including an abhorrence of that most cruel of all activities, warfare. *Moreover, of all people, the biologist must have a deep appreciation of all forms of life and a reverence for life itself.*

The personal qualities which improve one's chances for success in biology are those desirable in any scientist, with a few especially applicable to biology. This does not mean that all biologists have to fit a pattern or that all biologists are alike. Biology, probably the most varied of all the sciences, is broad enough to challenge anybody possessing curiosity about the nature of the world and of its life.

## SOME PERSONAL ATTRIBUTES OF BIOLOGISTS

### Enthusiasm

The personal attribute which heads most lists of desirable traits for scientists is genuine liking for the subject. Do you enjoy studying biology in high school or college? Do you like to read about science in magazines and newspapers? Have you ever made a collection of "nature" objects or made a special study of any group of living creatures, such as flowers, trees, butterflies, or seashells? Do you like to attend scientific exhibits, or have you ever taken part in a science show? Do you find the performance of laboratory experiments an absorbing interest? Do you like to work with animals or with plants? If you can answer most of these questions with a "yes," you may have one of the most important qualifications for success in a biological career.

### Intelligence

Don't let the heading of this paragraph give you the wrong idea that only those of extraordinary intelligence can be good biologists. Emphatically, one does not have to be a genius to succeed in science; the Einsteins and the Pasteurs are few and far between. People with an extremely wide range of talents can find a place in the life sciences. As in any field of endeavor, of course, those with keen mental alertness and better-than-average intelligence stand a better chance of getting to the top.

The ability to reason both abstractly and concretely-that is, to solve problems, such as algebraic equations and also to understand the significance of new observations—will be useful, especially in research. When new facts are presented, one should have the ability to fit them in with things already known. At times, the new facts upset one's previous prejudices and notions; the biologist must be prepared to adjust his thinking accordingly. This capacity for intellectual growth is probably more important than is the possession of a high degree of "native intelligence."

### Curiosity

Others who have thought about the personal attributes of biologists have all given a prominent place to curiosity. Some years ago, the American Institute of Biological Sciences put it as follows: "This inquisitive outlook, this penetrating quest for the truth, is the most distinguishing characteristic of all biologists."

Advances in science have been made by those who *wondered* about things. This attribute is especially important for those who will enter biological research, but surely is not out of place even in the performance of routine lab or field work. In addition, for the teacher of biology the ability to foster an inquiring state of mind in one's pupils is a precious asset. If you wish to seek new frontiers of knowledge, there is no subject which will give you more satisfaction than biology. The quest for new knowledge takes biologists all over the world, from the icebound continent of Antarctica to the steaming jungles of tropical islands, and from the tops of mountains to the floors of the deepest seas. Biologists are also in the forefront of the space program and in many laboratories are devoted to the conquest of disease, even delving into the nature of life itself.

**Open-Mindedness**

We have already pointed out that a good biologist is willing to discard an old notion if it does not fit newly discovered facts. This is such an important qualification that it warrants having a section of its own in the present list. It should be made clear that there is a difference between being open-minded and in being vacillating; one should not be blown about by every change in the wind. Moreover it is the *interpretation* that changes, not the facts themselves. An observation made with sufficient care should be valid indefinitely, but the things seen by an observer may change with alterations—often very subtle and ill-defined alterations—in the conditions under which an observation was made. As the famous physiologist, Dr. A. J. Carlson (known affectionately to his friends and pupils as "Ajax") used to say: "Vot iss de effidence?" A good biologist forms opinions, not on the basis of preconceived notions, but on observed facts.

**Precision**

It will be useful to many biologists to be able to make observations with great accuracy and to detect minute differences between objects or events. Two kinds of plants or two kinds of insects may look so much alike that the untrained observer would think they were the same, though they may be different species; that is, so different that they cannot interbreed. It may be equally important to recognize similarities. Small differences may also be important in laboratory results. If you feel that you cannot make such fine distinctions, it may be because you have never been called upon to do so; the ability to make accurate observations is a quality that can be learned, and every serious student of biology receives training in it.

**Patience**

When the great German biologist, Paul Ehrlich, sought to find a chemical compound which would destroy the parasite *Treponema* without killing the patient, he finally found it after trying 606 different substances. Although "606" has been long since superceded by better and safer remedies, its discovery was an important milestone in the history of biomedical science, for it initiated the era of *chemotherapy;* that is, the treatment of infectious diseases with chemical compounds. Up to that time, the only agent that could be classified as "chemotherapeutic" was

the ancient remedy quinine which was extracted from the bark of a tree—cinchona—and used to kill malaria parasites. In that prechemotherapeutic age, Oliver Wendell Holmes, a physician as well as a poet, told the Massachusetts Medical Society: "If the whole *materia medica* as now used could be sunk to the bottom of the sea, it would be all the better for mankind—and all the worse for the fishes."

If Ehrlich and his assistants had lacked patience, they might have said, "We will try 600 substances and if none of them work, we'll give up." This great advance then would have had to await the appearance of a more patient investigator. Actually, Ehrlich was extraordinarily lucky, for most modern drugs are selected after trials of many thousands of substances. One of the modern antibiotics, terramycin, for example, was found only after the study of nearly 100,000 molds!

It is true not only in the field of drug therapy but in nearly all biology that most trails lead nowhere. One doesn't know that a trail is a blind alley until it has been explored, so one must follow a path for a while, then start all over again. Often the same manipulations and observations must be repeated over and over again with a minor modification each time until the true path is found. It is not commonly appreciated by the general public that success is the exception rather than the rule, and that there is a great deal of trail and error associated with every great discovery. But most investigators take keen pleasure in the pursuit of knowledge and the joy of discovery—whether in the laboratory, the field, the classroom, or elsewhere—which more than compensates for the long period of testing and measuring and repeating that goes on beforehand.

## OTHER PERSONAL ATTRIBUTES

The list of desirable attributes could be continued until it included everything we admire in people. There are, however, certain qualities which are especially helpful in particular kinds of jobs. Most biologists will need to exhibit a willingness to work with others and a genuine liking for people. These attributes are obviously desirable for teachers, but are usually an asset in other kinds of work as well, for the days of the "lone wolf" are pretty much in the past. Most work today is done in cooperation with others. In some types of laboratory work manual dexterity would be a valuable asset, particularly when one must manipulate very small objects. Th degree to which this is required varies greatly among different types of biological jobs.

Writing and speaking ability will help not only teachers but others as well. The higher one advances, the more important it becomes to be able to communicate with fellow scientists. A biologist obtains an enviable reputation only if his fellow scientists understand what he is doing, and this is communicated in the form of papers published in professional journals and in lectures at meetings and conventions. To a considerable degree, an aptitude for speaking and writing can be learned by study and practice, so you should not be discouraged if you feel that you lack this aptitude. For that matter, there are many very fine jobs in bioscience that do not require public speaking or writing, but generally these are not the top grade jobs in teaching, research, or administration.

Certain specialized attributes will be helpful in specific types of jobs. For example, some of the duties of the wildlife biologist may require considerable physical stamina and strength, with some competence in outdoor craft. Arduous outdoor activity, sometimes in remote areas, may be required. On the other hand, there are laboratory and office jobs in wildlife biology, too.

Some of the attributes listed above are somewhat special—particularly enthusiasm for the subject, curiosity, open-mindedness, and patience. Perhaps you feel uncertain as to whether you possess the requisite attributes. If so, you should not feel discouraged, for if you'll review the list above, you may notice that by and large they are attributes toward which anyone can aspire, and many of them can be acquired. At least one attempt has been made to prepare a test by which you can get some idea of your aptitude for science. It is called *Test Yourself for Science,* obtainable from the Committee on Career Guidance, Scientific Manpower Commission, 2101 Constitution Ave. N.W., Washington, D.C. 20418. It is written with the idea that if you enjoy working the problems in the booklet, this might give you one small clue as to whether or not you might enjoy spending the rest of your life with scientific problems.

The chances are that if you have gotten this far reading this book and if you have had some courses in high school science, you already have a fair idea as to whether biological science appeals to you. If it does, and if you are willing to work faithfully, you should be able to succeed in a biological career and find immense joy and satisfaction in it. If you do decide to follow such a course, you will find that the rewards are great.

## WOMEN IN BIOLOGY

Although women constitute the majority of the population of the United States, women scientists are still decidedly in a minority. This is somewhat less true of biological sciences than of physical sciences, since about a quarter of all women in science are in biology. Those who have succeeded leave no doubt about the capabilities of women as scientists, but some have had to overcome obstacles that traditionally have been placed in their way. Legislation making sex discrimination illegal has prompted many administrators to actively recruit women. It has led to a surge of interest in removing barriers and in encouraging more women to consider a career in science. Articles attesting to this interest appear from time to time in various professional journals and books.

There is evidence that the outlook for women is improving. Indeed, if one looks at it from a historical perspective, vast improvements have already taken place. For the first two hundred years of higher education in this country— from 1636 when Harvard was founded until 1837 when Oberlin was opened—no woman could attend college. When Bryn Mawr was opened as a woman's college in 1875, there were said to be only four women Ph.D.s in the entire world. Since Bryn Mawr hired only Ph.D.s for its faculty, the faculty had to be made up of men. Recently, several traditionally all-male colleges have opened their doors to women students, though it is uncertain how much of this enlightened policy is attributable to a desire for fairness and how much to economic considerations. However, there is no doubt that much of the recent improvement in the status of women in professional life is because of an increasingly mature attitude on the part of the American public, as well as the application of federal laws against discrimination.

At all school levels, many girls receive better grades than boys, and research has indicated that young women of high school age do not lack the intellectual potential of becoming scientists. Nevertheless, skills and interests related to science are more apparent in boys than in girls, even as young as the junior high school level. Parents usually treat girls and boys differently even during early childhood. Boys are taught to be independent and to reason and think analytically. They are often given toys which help to develop mechanical or science-related interests and hobbies. Early familial influences on girls, on the other hand, are frequently related to preparation for motherhood and for dependence upon the future mate.

By the time the young man or young woman is in high school, he or she

is given the opportunity of choosing certain electives. Such intellectually demanding subjects as mathematics, chemistry, and physics have traditionally been more frequently elected by boys than by girls. This has been identified by some writers as an important barrier to women's participation in science—it has been called the "mathematics filter." Success in science has so often been correlated with talent in mathematics that any person contemplating a scientific career should not avoid acquiring mathematical skills. The requirements for a woman in biology are exactly the same as for a man: a serious interest in the subject, a willingness to spend the time and effort necessary to train for it, and a desire to contribute to its advancement.

During the years of early adulthood—18 to 25—society expects men to concentrate on preparations for a career, but the important decision for a woman is thought by many to be whether or not to have a career in addition to marriage. Some have felt that women could not combine great success in both a career and marriage, but it is not difficult to find women bioscientists who attest to the falseness of this myth. Inspiring examples of successful scientific careers among women may be found in such books as *Women and Success* by Dr. Ruth B. Kundsin, and *Women in Science* by Alice Fins (See Appendix).

Women work at all levels, though there is no doubt that their numbers are relatively fewer in the higher than in the lower echelons. The success of women as teachers, whether of scientific or nonscientific subjects, is too well known to need elaboration here. In addition to teaching positions, there are many other openings for biologists, as we shall see in later chapters. Many women—and men as well—find satisfaction in working as laboratory assistants, technicians, medical technologists, and related jobs. The majority of such workers are women. For some, it is a temporary job, but for many it is a fulfilling life-long career.

Some of those who take employment as laboratory assistants and the like will wish to study for advanced degrees and achieve high professional status. Many women follow this course, though in doing so they may meet with other barriers. To go on to graduate work for an advanced degree, a student requires a sponsor who is a full time faculty member. Most of these are male, and even though a prospective sponsor may not consciously practice sex discrimination, the perception of a female student may be subject to unconscious bias. The sponsor may wish to be sure that the student is "committed to a career." Most graduate students need financial assistance, and much of this is provided by grants. Grant administration is

largely dominated by males. Such barriers are less of a problem than in former years, and are not so formidable as to prevent an increasing number of women's successfully surmounting them.

As more and more women become successful in scientific careers, they can serve as role models for succeeding students. So many have succeeded that the U.S. Department of Labor has stated that women have amply demonstrated their scientific abilities. Young women who are just contemplating a future career should not believe any inference from any source that they are any less capable than their male counterparts. Those women who have studied bioscience and remain in the field do so because of their love for the subject and their interest in it. An educated person, man or woman, is likely to seek employment not merely for financial reward, but even more for those intangible rewards that come from solid achievement, recognition by one's fellow man, and service to society.

## MINORITIES IN BIOLOGY

Some minority groups have fared well in biological science, but others are woefully underrepresented. The situation has been frequently studied and widely deplored. Generally, it has been concluded that at present, lack of participation is a more important factor than outright religious or racial prejudice. In a study of careers in biosciences, B'nai B'rith has stated: "... Jewish youth seeking a career in biological sciences are not hampered because of religion." A report by the National Research Council has pointed out that of all racial and ethnic minorities holding doctorates in biological sciences, the majority are Orientals.

A number of efforts have been launched to acquaint black youth with the possibilities existing for scientific careers in general and bioscience careers in particular. The *Black Collegian* in their issue August-November 1982 published severed articles on career opportunities, including one titled "Biology Careers are Alive and Well." It is pointed out that blacks have made great advances from slavery through "second class" citizenship to the verge of nominally full equality. In order to continue and to improve upon that progress, it is necessary to acquire the training and skills which will give the black student an advantage. It is encouraging to note that in the new generation, students are bent on taking advantage of opportunities, in contrast to those in the turbulent sixties who sought answers by dropping out of school or in taking courses irrelevant to the technological age.

Students who wish to prepare for graduate study in the health sciences can be aided by the Minority Biomedical Research Support (MBRS) Program. MBRS is specifically aimed at increasing opportunities for students to participate in biomedical research at colleges and universities with high enrollment of minority students. The program is administered by the Division of Research Resources of the National Institutes of Health, which is the biomedical research arm of the Federal Government.

Opportunities for minority members of society do exist in the biosciences, and they are further improved by "affirmative action," which requires institutions receiving federal funds to show that they are equal opportunity employers. If our citizens of ethnic and racial minorities are to gain their proper place in science, it will be necessary for them to realize that opportunities really do exist, and to enroll in science courses in greater numbers than in the past. Some studies suggest that a high proportion of black children grow up under circumstances that fail to encourage the creative talent necessary for science. However, the number of black parents with college educations is increasing, and this bodes well for the future.

Science is not always presented to the young black student as something he or she can and should consider as a career. Eminent blacks who are held up as models for the young are likely to be celebrities from the world of entertainment or sports rather than scientists. Career days often don't bring black professional people to talk with students, and job fairs sometimes fail to point out that professional careers are open to minorities.

One of the best known black scientists was Dr. George W. Carver, whose experiments with peanuts made him world famous. Dr. Charles Drew became so well known as an expert on blood banks that he has been called "Mr. Blood Plasma," and he became a director of the American Red Cross. Dr. John T. Wilson became director in charge of many laboratories, including those of biochemistry, microbiology, histopathology, physiology, and toxicology in a large industrial laboratory. Such examples show that it is possible for a member of a minority group to achieve success and even distinction in bioscience.

## THE DEMAND FOR BIOLOGISTS

It is difficult to appreciate the rate at which science grows and continues to grow. Much of this growth has taken place within the lifetimes of peo-

ple still active, for it has often been said that more than 90 per cent of the scientists who ever lived are alive and active today. Not only has biology shared with other sciences in this growth, but there are some indications that biology's share may be increasing. Reliable statistics are not easy to acquire, and projections for the future don't always turn out as expected, but several surveys have been made to show how the demand for biologists has grown in the past and "best guesses" of what it will be in the future.

Employment opportunities for scientists and engineers in general, and for bioscientists in particular, continued to increase even during the recession years of the late 1970s. For example, the expenditures for research and development by American industry grew at an annual rate of 5.1 per cent in real dollars during the last five years of that decade. The number of scientists employed grew by 30 per cent from 1976 to 1981, according to a report by the National Science Foundation (NSF). A survey by the NSF during the early 1970s showed that the number of Ph.D.s awarded in the biosciences in the United States during the 1960s was *ten times* as great as in the 1920s, and they predicted that bioscientists holding doctor's degrees and actively working would increase from 57,000 in 1972 to 92,000 in 1985. However, that prediction seems to have been rather on the low side, for the Bureau of Labor Statistics of the U.S. Department of Labor reported a figure of 90,000 bioscientists employed in 1980.

Statistics such as these are primarily focussed on those who have gone through the lengthy and arduous process of obtaining doctorate degrees. It is not easy to obtain similar surveys of employment by those interested in bioscience who have not completed such a full course of study, but there are estimates that for each biologist with a doctor's degree, there are at least three to five with biologically related occupations requiring one to four years of preparation. Many pleasant, profitable, and personally rewarding opportunities are available in this category, and we shall discuss these in a later chapter.

## REWARDS OF A BIOLOGICAL CAREER

An ideal career should be able to supply you with sufficient income to provide you and your family with a standard of living comparable with others of similar education and experience; reasonable opportunity for advancement; recognition by society as one who is engaged in useful work; a feeling of self-esteem and deep personal satisfaction that comes from work

sufficiently challenging to develop one's capabilities to the fullest.

To find out how bioscience measures up in these areas, you might talk with as many biologists as possible. It is a safe prediction that most of them would feel that biology offers a great deal in each category. There may be ways to obtain greater riches, or easier routes to fame (for example, in sports, entertainment or politics) but if asked to make career decisions again, most biologists would probably choose either the same career or one very much like it.

The rewards which you seek may be tangible and intangible. The tangible rewards include working conditions and salaries. Most biologists work either in laboratories or classrooms or both. By and large, such places are comfortable, clean, well lighted and adequately equipped. Many others work in the field, or experiment stations, or on research vessels. Wherever a biologist works, he or she will usually find whatever office space, library facilities and other services are needed, and these are generally supplied at the expense of the employer. Very few work as "lone wolves"; most will work in the company of others, and there will be stimulating interactions among fellow scientists, technicians, assistants and others. For those few jobs involving the handling of hazardous materials, special training is available for safety and security.

No exact figures can be given for what your salary as a biologist will be; many factors affect the amount. Salary surveys are periodically released, but changes are so frequent that they are out of date by the time they are printed. For example, a study released in 1975 by the Commission on Human Resources of the National Academy of Sciences gave the median annual salary in 1973 for those with doctorate degrees or equivalent as $19,500; that is, half of those employed received more than $19,500 and half received less. This figure had increased from $15,000 in 1970, but it may be noted that the figures were already two years out of date by the time they were published. The upward trend continues, as witnessed by a survey by the Bureau of Labor Statistics of the U.S. Department of Labor, published in 1983 (surveying salaries as they were in 1981). This survey quoted the College Placement Council as noting that even beginners with a baccalaureate degree in bioscience drew a median salary of $15,200, and the median salary for bioscientists at all levels employed by the federal government was $28,100.

The National Center for Educational Statistics pointed out that salaries for faculty members in colleges and universities vary widely, depending upon the rank of the teacher, the type of institution—public or private,

two year or four year and so on—and whether the contract is for a full twelve month year, or a nine month school year. The figure given in this study for the year 1981 was an overall average of $23,267, the averages ranging from $15,179 for beginning instructors to $30,738 for full professors. It was pointed out that the overall compensation was actually higher than these figures suggest, for 85 per cent of those surveyed were paid on a nine month basis, and had supplemental income for summer work. Supplemental income for faculty members in biological sciences include teaching in summer school, earnings for lectures, writing, research grants, and consultation for private industry. In many cases, tuition waivers are avilable for family members, and some institutions award housing concessions. Opportunities for travel, including sabbatical years with full or part salary, are also generally available. According to the American Physiological Society, physiologists in 1982 earned from $12,000 to $20,000 as beginners and up to $50,000 for advanced professionals.

Laboratories in industry have traditionally paid slightly more than government laboratories which, in turn, paid more than schools, hospitals, or private research foundations. The gaps have seldom been as wide as many people have supposed, however, and they have become so much narrowed in recent years that industry has had to increase its offers in order to preserve any gap at all. Even that has not always been successful, particularly with the increased salaries offered for some government positions. Salaries vary somewhat in different sections of the country, but the variation is accompanied by similar differences in the cost of living. Hence, the type of employer you choose and the place where you live will determine salary to some extent, but the difference will seldom be great enough to make the size of the salary the principal deciding factor in choosing a job. Sometimes, possession of a skill in high demand and short supply will enable the holder to command a significantly higher salary than most others at a comparable career level. At present, this would be true of clinical pharmacologists and of veterinary pathologists, to name two.

It would probably be out of place to discuss salary figures in much more detail, since by the time you read this you will have to check on the current picture anyhow. But the following points are worth emphasizing:

- Salaries paid to biologists are in the middle income brackets and are adequate for a reasonable standard of living.
- Biologists' salaries compare well with those of other scientists and are higher than those of some non-science academic disciplines.

- Merit is rewarded by advancement and salary increases.
- It pays to obtain the highest degree possible.
- The most successful biologists do not make as much money as the most successful physicians, lawyers, or businessmen. Therefore, if your primary goal is to get rich, you should not enter the profession of biology. However, there are many compensations in the life of a scientist that cannot be measured in terms of dollars and cents. In the paragraphs below, we shall mention a few of these.

## INTANGIBLE REWARDS

Although practically everyone needs and appreciates a good paycheck, to the average biologist the deepest satisfaction about his career comes from things no amount of money can buy. For example, for the high school or college teacher of bioscience, the thrill of watching young people with keen minds react to the excitement of science cannot be described, only experienced. The delight and wonderment which the young show in living things and the satisfaction which the teacher has in observing comprehension and enthusiasm appear on the faces of students are the rewards of teaching. But this is not all. Some of the students will choose bioscience as a career and extend the teacher's influence to yet another generation— and even those who do not choose a career in biological science may continue an interest in living things and an attitude toward life which will reflect the influence of good teaching.

Research work, administration, or any other kind of service in bioscience has intangible rewards no less than those of teaching. Think of the number of people you know to whom their daily work is "just a job." Also think how much of life people miss if they do not find pleasure and gratification in their day-to-day occupation! If there are any such people in biology, they are in the wrong profession. One of the most obvious things about life science is the enthusiasm most biologists have for their life's work. Not only is the work itself interesting, but most bioscientists take pretty seriously the idea that their efforts are worthwhile and that they can leave the world a little better than they found it. Perhaps this is one reason biologists are so much inclined to talk shop after hours, and maybe it explains why so many of them continue studying, thinking, and working after retirement.

Students in university biology classes, above, at University of Vermont, Burlington; below, at Core Arboretum, West Virginia University, Morgantown.

CHAPTER 3

# EDUCATION OF A BIOLOGIST

According to the *Occupational Outlook Handbook* published by the Bureau of Labor Statistics (1982-1983 Edition), the outlook for employment opportunities in the biological sciences will remain good throughout the 1980s for those with advanced degrees, but those with lesser degrees may experience competition. If you are considering a career in bioscience, then, you will find it to be to your advantage to obtain as much education as possible. Most of the careers to be discussed in this book require education beyond the high school level. Graduate study beyond the baccalaureate will be advantageous, and indeed will be necessary for the topmost jobs.

It will be seen in succeeding chapters that there are many biologically oriented careers other than research or teaching for which advanced degrees are not essential. Professional biologists who wish to have the greatest choice of jobs may wish to climb the traditional ladder which includes: first a high school course with several science subjects, then a college course with broad training in the first years followed by a concentration on the "major" subject, then after graduation a more intense concentration on a narrower aspect of the major through the acquisition of a master's degree and finally a doctorate. All these steps are important for those who will fill the highest positions as research scientists or university professors. Indeed, some have found it advantageous to go even further, through a period of postdoctoral training—somewhat comparable to the internship and residency requirements of a medical specialist.

There are a host of problems facing our society which can best be solved by those with some biological orientation, and one can scarcely be considered to have a well rounded education without some knowledge of bioscience. There are also a large number of biologically oriented jobs in cer-

tain industries—some manufacturers of food products, for example—which do not require the specific training of a biology major. This book, however, will be confined primarily to discussion of occupations which can be considered to be biological vocations.

If you are considering a career in biology, the level of education you pursue beyond high school depends upon what place you wish eventually to assume on the biological team. If you wish to work in a laboratory, there are schools which take high school graduates and train them in a couple of years to be laboratory technicians. Their graduates have no trouble obtaining jobs with good pay. They work in doctors' offices; hospital laboratories, or in various research centers. For advancement, however, further education must be obtained. For one of the best jobs as a laboratory technician, you will need to finish college.

It is not unusual for a young high school or college graduate to accept a job as laboratory assistant or technician with the intention of continuing study as time permits, earning credits toward a degree. Some have gone all the way through college and on to the Ph.D. degree this way. It may be done by part-time schooling or by alternately working and studying full time. Some employers, especially industrial laboratories and some government departments, encourage employees to improve their education by permitting time off for class attendance and by paying tuition bills.

The baccalaureate degree qualifies one for many teaching jobs in elementary or secondary school, but the additional one or two years of study needed to obtain a master's degree offers an additional advantage. At least an additional two or three years are required for the doctorate. With exceptional good fortune, the doctorate can sometimes be earned within three years after graduating from college, but the typical graduate student in bioscience receives the Ph.D. degree at the age of 31, seven years after the baccalaureate. In the meantime, he has had three years of professional experience. The person with the doctoral degree is equipped to fill the most exciting and challenging jobs in research, if research is his goal. The best jobs in industry, government laboratories, independent research institutions, or university faculties are also available to those who have pursued their education through the doctoral level.

This may seem like a long and discouraging prospect, but remember that during all those years you will be learning things that are beyond anything you have dreamed of. If need be, you can be earning while learning. In the end, your rewards will be not merely an adequate livelihood, but satisfaction in a life's work that no money can buy (see Chapter 2).

## HIGH SCHOOL SUBJECTS

It has been said that the scientist speaks with three kinds of languages: English, mathematics, and foreign languages. High school is not too soon to start the mastery of all three. English is the language you will be using to communicate with your fellow students and with your fellow scientists; you should strive to speak and write it correctly, concisely, and with the precise meaning you wish to convey. Unfortunately, many scientists are deficient in this regard. Editors of scientific journals frequently complain about the quality of the writing in papers submitted to them for publication. If you can learn to speak and write clearly, you will find your path smoother no matter in which direction you wish to go. Your colleagues will appreciate and respect your ability to communicate. So study as much English as possible, work hard on composition, and read, read, read.

The use of mathematics varies greatly among the various fields of biology, but more and more biologists need to know calculus and statistics, at least. For some of the newer fields of research, such as molecular biology and biophysics, more advanced mathematics is required; the mathematics requirement is more fully discussed in the next section of this chapter.

Science knows no international boundaries, and much of importance to biologists—especially if they are engaged in research—is published in languages other than English. At international gatherings of bioscientists, it is necessary to communicate with people who speak other languages. For these reasons, certain language requirements have been established for students majoring in biology or other sciences. The high school student intending to go on through graduate school should anticipate these requirements and start language study as early as possible. If language study is postponed, it would require time that the advanced student would prefer to devote to his specialty.

In addition to English, mathematics, and language, high school students interested in any science should include chemistry, physics, and biology in their programs. With these studies, together with the basic requirements for graduation, the student will enter college well prepared to pursue any course of study—biology, another science, or nonscience. If after discussing your plans with your guidance counselor you feel unsure about whether you wish to prepare for a career in biology, or for that matter, if you don't even know what your major in college will be, you should not feel discouraged. It is too frequently not recognized that it is the exception

rather than the rule for a student at the beginning of college to be certain what his future will be, and many young people discover new interests after they have been in college for one or two years and change their career goals then or even later. If you have a proper foundation of knowledge in English, mathematics, languages, science, and the humanities, you are prepared to undertake a study in any field of endeavor. Without any one of those fields, your education is less than complete.

## COLLEGE REQUIREMENTS

The choice of a college presents no unusual difficulties for the young person intending to study biology. All—or nearly all—of the better colleges have departments of biology that range from adequate to excellent. In most instances the choice of a college for undergraduate study may safely be made on grounds other than the size or research reputation of the biology department. Of course, the biology department of the chosen college should be able to present a good solid major in biology; one way to judge its adequacy is to inquire whether the graduates of the department have been accepted in programs for advanced degrees at outstanding universities.

I cannot emphasize too strongly that you should not feel impelled to consider only Ivy League colleges, or others of similar age or social standing. They are fine schools, and their reputation for excellence has been well earned, but they do not have the monopoly on academic achievement that some status-conscious but ill-informed people may believe. Many of the outstanding biologists of recent years were graduated from colleges that are little known to the general public outside of their nearby communities. These colleges are widely dispersed geographically, and there is no one section of the country that can claim an outstanding advantage. Indeed, several surveys have been made of the academic origins of scientists. The surprising finding is that the small colleges of liberal arts that are scattered in such profusion throughout the country contribute a disproportionately large number of biologists and other scientists.

The American Institute of Biological Sciences has compiled a complete list of all colleges offering biological training. Entitled *Directory of BioScience Departments in the United States and Canada,* it is available in many libraries. At this writing, the last updating of the Directory was in

1975, but it is safe to assume that changes in the list do not occur very often.

In your preparation for a career in biology, you will continue in college many of the subjects which you studied in high school. You will be able to plan your course of study according to your individual needs and preferences; you may have a member of the faculty assigned as your specific advisor. In this chapter we can give you no more than a few general statements about the kinds of studies you will need. During the first two years, most students will take courses in a wide variety of subjects to obtain a broad education. In the last two years, they specialize more and more in the major field, with a somewhat less thorough specialization in another (usually related) field called the "minor." Most biology majors have "minored" in chemistry, mathematics, or physics, though in recent years some have minored in anthropology, sociology, or psychology.

The specific courses in bioscience which a biology major takes will vary depending upon which branch of biology is chosen and upon those offered by the college. Generally speaking, the larger colleges offer a greater variety of courses. In some instances, separate majors may be offered in various fields of biology; that is, you may major in botany, or in microbiology, or in zoology, etc. For most students, it would be unwise to specialize too strongly at an early stage. An old edition of a career brochure prepared by the AIBS put it this way: "Give yourself a chance to understand the breadth of biology before you concentrate on the blood flow in the muscles of a frog's leg." Some kind of a "core" course is often offered to give the student a bird's eye view; you should familiarize yourself, not only with the different branches of bioscience, but with the careers offered in applied biology as well.

After deciding to major in biology, most students will seek to know something about cellular biology, study the fascinating facts of heredity (genetics), learn how the organs of the body function (physiology), obtain some knowledge of systematics and ecology, and find out what is known about the changes which occur with the passage of many generations (evolution). Comparative anatomy, embryology, and microbiology will also be on the list. Even if the student does not take a specific course in each one of these subjects, it is essential to become aware of the general principles of all of them, regardless of what biological specialty is eventually settled upon. After finishing, the student will find that he or she is equipped not only to go on to graduate school, but the requirements have

been met for entering the study of such specialties as medicine, dentistry, veterinary medicine, agricultural science, and many other professions.

While the student is studing biology, the other sciences will not have been neglected. Indeed, an understanding of biology requires knowledge of other sciences. Although a wide range of options may be available to the student in the third and fourth years of college, there is a growing tendency to require a core of mathematics and physical sciences common to all options. An example of this is a statement prepared by a Committee on Undergraduate Curricula of a major university which stated that the B.S. degree in biology "should provide an introduction to the areas of mathematics and physical sciences of sufficient intensity to permit the student to perceive and think in terms of the physical and quantitative components of biological phenomena."

What these words mean in terms of practical requirements for the student may be summarized somewhat as follows: after a preparation in high school including introductory chemistry and at least one and a half years of mathematics, the student continues mathematics through calculus, analytical geometry, and elementary statistics. For some biological specialties, that would not be enough mathematics—some biophysicists recommend as many as ten courses in mathematics for their specialty. General chemistry, organic chemistry, and physics must also be a part of the curriculum for those intending to become professional biologists at the graduate level.

These requirements will vary somewhat with different colleges, but by and large you may be expected to be prepared to fulfill most or all of them. It was not always so. Some very successful older biologists in certain fields—notably anatomy, botany, and zoology—received their training when such a rigorous schedule was not in vogue. Yet, even in these specialties you will find that the actively working bioscientists will recommend that their students become fully equipped with the tools provided by mathematics and physical sciences.

The above does not complete the list of subjects that biologists may need. Some of these will be mentioned in succeeding chapters when some kinds of biological careers will be discussed. Biochemistry, psychology, and geology are among the subjects that will appeal to some biologists. Students intending to study for advanced degrees will also expect to be required to show some facility in reading biological literature in one or more foreign languages. Language study should start in high school and continue in college. Language requirements have changed considerably over

the past generation or so. Not long ago, all high school students planning to go to college took two or more years of Latin in addition to a modern language. Nowadays, no college requires Latin for admission, and most high schools do not teach it. Probably most of the Ph.D.s in bioscience obtained their degrees when a reading knowledge of both French and German were required. Gradually, it became possible to substitute another language—Russian or Spanish, for example—for one of the traditional languages in special fields. Even that has been changed in many schools, with only one language required. In certain fields (fisheries research, for example) more current research is published in Russian or Japanese than in French or German.

The language requirement for the doctoral degree can be met with less knowledge of a language than is necessary for fluency in speaking, reading, or writing, but the student would find it advantageous to acquire fluency, if possible. There are increasing numbers of international meetings attended by biologists from many countries. Although most of these people speak English (with varying degrees of proficiency) and the majority of the talks at many meetings are in the English language (all educated continental Europeans seem to be better linguists than the average educated American or Britisher), anyone attending finds it most profitable to possess more fluency in a foreign language than the minimum necessary to pass the usual college examinations.

I would not want to close this discussion of the undergraduate education of a biologist by leaving the impression that the student need study only English composition, sciences, and languages. A biologist is a member of the intellectual community and cannot properly fulfill her or his function in society—or even be a good biologist without being an educated person. The student biologist should, therefore, take advantage of the opportunity to learn as much as possible about history, philosophy, economics, religion, the arts, or whatever liberal arts subjects have most appeal or which are recommended by the advisor. In today's world, the truly educated person must have more than a little exposure to *both* science *and* the humanities.

## GRADUATE STUDY

In many foreign countries, there is no exact equivalent to the baccalaureate or master's degrees, but the Doctor of Philosophy is universally

recognized and respected as the highest official reward for the completion of a course of study aimed at the training of scholars, teachers, and research workers. In the United States, the first Ph.D. program was initiated by Yale University in 1860. There are some variations in the requirements from one university to another, but essentially they all include: completion of certain prescribed courses; fulfilling requirements for a reading knowledge of one or more foreign languages of material in the candidate's major (this requirement has varied more in recent years than have the others); writing a dissertation (thesis) which presents and discusses the results of the student's original research; and passing special examinations, usually consisting of written examinations testing the student's broad knowledge of the subject, and a final oral examination centering upon the points covered by the thesis.

These sound like formidable requirements—and they are. But students in the biosciences have been increasingly successful in satisfying them. Since the mid 1950s, when about one thousand doctoral degrees were rewarded annually in the biosciences, the number has approximately doubled each decade. The young people obtaining these degrees are equipped, insofar as formal education can equip them, to obtain desirable employment at once and ultimately rise in their chosen profession as far as their abilities and achievements will carry them.

The degree of Doctor of Philosophy (Ph.D.) has a venerable history, and may be rewarded in many fields having no relation to science. Some universities, wishing to emphasize the concentration on science, award the degree of Doctor of Science (D.Sc.) rather than the Ph.D., just as in some instances the baccalaureate degree is B.S. instead of A.B. In each case, the degrees are equivalent. There has also been a movement in some places to award a different kind of doctorate: the Doctor of Arts (D.A.) degree. The idea behind this degree has been that the Ph.D. degree, with its emphasis on research, does not provide the proper preparation for teaching, even though about three-fourths of all Ph.D.s become college teachers. The training for the D.A. is intended to be as rigorous as that for the Ph.D., but with the emphasis placed upon preparation for teaching rather than for research. The program is controversial, and has not caught on universally. It remains true that in most institutions of higher learning, promotion and salary increases are based upon research success and especially upon scholarly publication. Often, teaching ability is scarcely considered and tenure may be denied to excellent teachers who have been less than prolific in publication—a situation known among college faculty members as

"publish or perish."

Either route to the doctorate may seem like a long and difficult path to you, but be assured that it is really not as bad as it sounds, and probably no worse than you would need to follow in any other professional career. Excellence in any field is attained only by hard work and devotion. The musician must spend long years practicing scales and exercises and learning musical theory. The writer must labor diligently over the typewriter even when the muse seems to have forsaken him, and he must work all the harder when his efforts have been rejected by himself, his editors, or the readers. Success in business, too, comes usually only after many years of hard work, sometimes accompanied by disappointing setbacks; the top business executive has usually spent his life in working long hours that make the traditional 40-hour week look like loafing by comparison. The difficulties in preparing for a career in biology are different, but they are not necessarily greater.

## MEETING EDUCATIONAL COSTS

The cost of an education in biology at the undergraduate level does not differ essentially from the cost of any other college education at the same level. Those who elect to continue their education in graduate school will usually find no difficulty in achieving an earning-while-learning status.

It is difficult to generalize on the costs of a college education; not only do the costs vary greatly among different colleges and universities, but in the past several years they seem to have increased each year. The high school student should not wait until near his graduation to decide what kind of college he or she wants to attend, to take stock of his financial resources, and to examine the possibilities available in scholarships and loans to help defray expenses. The student should make full use of the information and help available from his high school guidance counselor and from other sources.

When the high school graduate applies for college entrance, he or she will find plenty of competition, even if the applicant has a good high school record and a high SAT score. There are some colleges that accept only the highest ranking high school graduates, and some of the prestigious colleges have many times as many applicants as they can admit. For this reason, some students get an exaggerated idea of the difficulties in being accepted in college. Some of the lesser known colleges may start the

school year with vacancies in the freshman class. Some of these can offer a highly rewarding four years of college, with good training in selected fields—some of them in biological sciences—at costs appreciably lower than those of the "big name" schools.

The student with a minimal budget may attend one of the community colleges that have sprung up all over the country. Attendance at a community college or at another college located within commuting distance of home may eliminate the expense of room and board, with a saving of $1,000 or more a year, depending on the cost of commuting. The AIBS has been especially helpful in promoting professional activities by bioscientists in two-year colleges, and many of these schools have developed programs in general biology comparable to (and sometimes better than) those in the lower divisions of some four-year colleges.

Every state has one or more land-grant colleges or universities; altogether there are 67 of them. They originally received the designation as land-grant colleges from an Act introduced into Congress by Senator Morrill of Vermont and signed into law by President Lincoln in 1862. The first grants were for the establishment of "colleges of agriculture and the mechanic arts." These colleges owe their very existence to developments in biological science. By the middle of the nineteenth century, the advances in zoology, botany, and physiology, as well as in chemistry, led to a demand to establish schools for the study and promotion of scientific agriculture. The land-grant colleges were a direct response to this demand, and they were originally called "agricultural colleges." They were founded as centers of research in applied biology, and they traditionally have strong departments of biological sciences.

Most of the land grant colleges have become state universities, but many of them can still offer a college education at a cost which is often several thousand dollars a year less than that prevailing at a private college of comparable eminence. During the late 1970s and early 1980s college tuition increased faster than the nation's inflation rate; college administrators blame this situation on several factors, including the necessity to bring faculty salaries within the limits of other professions, and to repair buildings that had long been neglected. The student faced with the necessity of meeing these costs will find, however, that the colleges have also increased financial aid to needy students. This often enables a student with limited financial resources to attend a more expensive school. The selection of recipients of scholarships and loans is usually based on need as well as on past achievements, so most of the funds are reserved for those who

need them most. Guidance counselors generally have much information on financial aids and the qualifications for applying, but it may also be helpful for the student to do some independent investigation.

The Bellman Publishing Co. P.O. Box 164, Arlington, Massachusetts 02174 publishes a book, *Scholarships, Fellowships, and Loans,* by S. Norman Feingold and Marie Feingold. This book attempts to list all sources of funds available for student aid. The information in the book is supplemented by a bimonthly news service, and the entire volume is updated from time to time. Volume VII, which appeared in 1982, listed more than 1,350 descriptions of funds—national, regional, and local—on 262 different vocational goals. Even so, the authors caution that their volume should be used only as a starting point, since there would be much information, especially local, which had eluded them. The kinds of aids are classified as scholarships, fellowships, grants, loans, scholarship loans (defined as scholarships which are converted to loans when the recipient fails to fulfill some requirement), work-study programs, awards, and prizes. Information is also given on any special restrictions which apply, such as residence in any particular state or locale, whether the student or parent must have some special affiliation or whether there are citizenship requirements, etc. Some funds, for example, are specially for certain ethnic groups, or for membership in a fraternal organization or labor union, or for former military personnel.

Most colleges have special loan funds administered by the college, and several organizations have established foundations which supply money for needy students. Some religious denominations have considerable sums of money for lending to students of their faiths attending colleges related to the churches—and these include some excellent colleges. Your guidance counselor can help you to obtain information, but the initiative must come from you, and it is your responsibility to fill our whatever application forms may be required and to get them in *on time.*

Biology students are particularly fortunate in the number of part-time jobs available to them. In addition to the usual types of jobs which any college student may fill, some colleges employ students as part-time laboratory assistants. In some instances, the advanced biology student may even help out in the laboratory teaching of elementary courses. This provides valuable experience as well as a modest amount of financial aid. Part-time jobs related to biology are especially available at land-grant colleges. These colleges often operate agricultural experiment stations which provide both part-time jobs during the school year and full- time jobs in

summer. The young biologist may even be lucky enough to find employment in a particular branch of biology which will turn out to be a major interest in life.

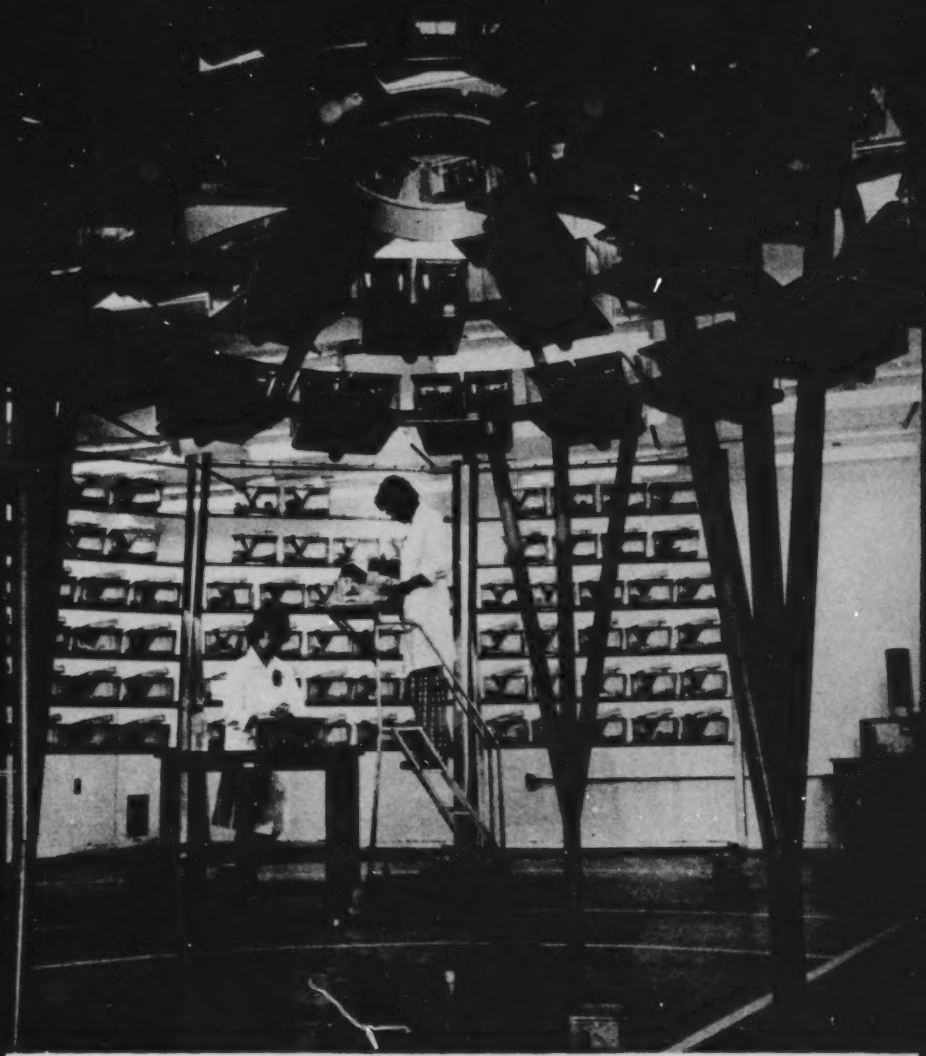
A word of caution should be given here. During a student's first year it is advisable not to accept employment which will take more than a few hours a week during the school year. Many people find the transition from high school to college a difficult one. The work is demanding, and new study habits may have to be developed. While this personal adjustment is going on, the student must remember that his or her first duty is to studies, and some limitations should be placed upon extracurricular activities including employment. For this reason, some authorities believe that one entering freshman year in college should have the full cost of the first year in sight before the start of the year, in the form of cash, expected help from family, scholarships, or loans, without needing to accept part-time employment. Such an arrangement is, no doubt, ideal, but not every beginning student can fulfill it.

Strange as it may seem, the financing of the graduate education leading to the doctoral degree is usually easier and simpler than that of the undergraduate years. Universities are eager to get talented graduate students for appointment as teaching assistants—or teaching fellows as they are often called. In return for their help in teaching laboratory work in beginning biology courses, teaching fellows receive cash stipends and often free tuition for their graduate studies. In the larger universities with numerous graduate students, so much of the teaching is done by teaching fellows that these universities are often criticized for lack of contact between the undergraduate student and the eminent professors who are listed in the university catalog as teachers.

Biological research at universities is often financed by grants from governmental agencies, private foundations, or industrial firms. A large share of these funds is used for fellowships and research assistantships for students. While some of these funds may be available for undergraduates, they are primarily for graduate study. Rather complete information on these sources is listed in the *Annual Register of Grant Support,* published by Marquis Professional Publications, Marquis Who's Who, Inc., 200 East Ohio St., Chicago, Illinois 60611. If at present you feel that you need not be concerned about financing graduate study it may be comforting to know that it may be available when you need it, if your college record is good.

Undergraduates and those just contemplating college will be more in-

terested in *The College Blue Book*, Macmillan Publishing Co. This is a monumental work in five volumes; the first two give descriptions and tables of data from 3,300 colleges in the U.S. and Canada. Volume 3 describes all the degrees offered by college and subject, while Volume 4 on Occupational Education tells where to train for technical subjects. Of special interest may be Volume 5, *Scholarships, Fellowships, Grants* and *Loans*. Similar information is available in *Barron's Profiles of American Colleges* (Barron's Educational Series, Woodbury, N.Y.); this is updated every year or two. Also kept up-to-date is the *Index of Majors*, published by the College Entrance Examination Board, listing all schools where any particular subject is offered as a major. Finally, summer jobs and internships and on-the-job training opportunities are listed in *Internships*, by Writer's Digest Books, Cincinnati. Your high school, college, or other local library should have these volumes available.



The low-dose-rate gamma ray facility operated by the Biology Division of Oak Ridge National Laboratory is used to study the effects of radiation on mammals. Photo: U.S. Department of Energy, photographer, Frank Hoffman.

CHAPTER 4

# VARIETIES OF BIOLOGICAL CAREERS

The group of sciences known as the biological sciences is so large and varied that there are many possible ways of classifying the numerous types of careers available. For example, they might be grouped according to subject matter: whether plant or animal or microorganism; whether the object of attention is a whole organism or the cells of which it is composed; whether one's interests are primarily in research or teaching or in practical applications. There are educational careers, industrial careers, health and allied professions—these and many more will be considered in the discussions which follow.

Growth and changes in the biosciences occur at such a breathtaking pace that it is difficult to keep up with them, and some of the most promising careers are in areas that were scarcely known only a few years ago. The late Frederic Joliot-Curie, one of the great physicists of the early twentieth century, is reported as having said that while the first half of this century belonged to the physicist, the second half would belong to the biologist. Some of the recent developments in biology seem to bear out this prophecy, and perhaps we can do no better in opening our discussion of various fields of bioscience than to start with some of the newer types of careers.

## BIOTECHNOLOGY

Biotechnology has been characterized as a "wonder world," which promises to revolutionize the ways in which we live, work and play. These rapid developments are the payoff of the cracking of the genetic code

stemming from the discoveries of the structures of genes—deoxyribonucleic acid (DNA)—in the 1950s. The potential of this research is beginning to catch the popular imagination to such a degree that a respected news magazine has compared it with "the discovery of fire, invention of the printing press and the splitting of the atom" (*U.S. News & World Report*, March 28, 1983). Whether this is an exaggeration or not, there is no doubt that the accomplishments already are impressive, and the future promise can scarcely be imagined. High school biology students today can perform experiments that the most sophisticated laboratories could not attempt a decade ago, and new jobs and even new kinds of careers are opening up.

Examples of what has already been accomplished are not hard to find. Members of the older generation can remember when diabetes was a certainly fatal disease. Then, in the 1920s, it was discovered that an extract of the pancreas of animals could aid in the treatment, and frequently prolong the lives, of diabetics. There were drawbacks, however. The animal insulin was not quite chemically identical to human insulin, and allergic reactions were encountered occasionally. Furthermore, it required a great and expensive effort to supply the demand. This state of affairs lasted for more than half a century, and by the year 1981 the pancreas glands from some 23,500 pigs and cattle had to be obtained from slaughterhouses for processing. Then came the biotech revolution. Using "gene splicing" techniques, appropriate fragments of human DNA, capable of catalyzing the production of genuine human insulin, could be inserted into a microorganism. The resulting bacterium—which can be considered a new form of life— needed only to be placed in the proper culture medium for economical production of the first pharmaceutical product to be marketed as a practical result of this research.

Other pharmaceutical products from similar research efforts include a variety of vaccines against such diseases as malaria, rabies, hepatitis, venereal diseases, foot and mouth disease in animals—and even cancer. One much publicized substance is interferon, a protein produced in our cells when exposed to a virus. Nothing has given greater hope as a "wonder drug" against an assortment of ailments ranging from common colds to cancer. So rapid are advances in research on this fascinating material that by 1981 a new scientific journal was established, devoted exclusively to research on interferon. It is clear, then, that anything written here will already be out of date by the time it is in print—a complaint often expressed by workers in biotechnology.

I would not want to leave you with the impression that drug manufacture is the only use of recombinant DNA techniques. Equally exciting, and perhaps of even more importance in the long run, are projects in the agricultural realm—food crops that resist the assaults of insects, or that manufacture some of their own fertilizer (as peas and beans do now), or that will grow in soils and climates that can not now produce food. Whole new species of plants have been created by gene splicing, such as crossing a potato and a tomato, and even a bean with a sunflower.

Biotechnology is not exclusively concerned with gene splicing, but includes several other types of techniques. For example, the technology of cell fusion, unlike DNA manipulation, deals with whole biological systems rather than small fragments. Cells that are formed by fusion of two different types of cells form a special type of new organism called a *hybridoma.* Hybridoma research is booming at such a rate that another new scientific journal concerned only with hybridoma research was started in 1981. Hybridoma are capable of producing antibodies against a wide variety of diseases, and are already being used as tools in diagnosis of many kinds, including bacterial diseases, prenatal disorders, and cancer. It has been predicted that the use of hybridoma for this purpose alone will form a two billon dollar industry by 1990. But even greater potential may be foreseen in the use in therapy of the antibodies produced by hybridoma.

Other types of biotechnology include test tube breeding of farm animals with embryo transfer, so that ordinary cows can give birth to super cows, for example, which can produce as much milk as three common cows. Many thousands of such superior offspring are already being produced. Genetic engineering may also produce superior meat animals. One could go on and on, limited only by the fertility of one's imagination—some day there may be improved microorganisms for turning waste into a useful energy source, microbes that increase the yields of oil wells, or that digest oil spills, sulfur metabolizing organisms that take care of important sources of air pollution—perhaps even bacteria that can manufacture proteins that will be far superior to silicon and metal as computer chips.

What does all this have to do with your choice of a career? Partly this: there has been an explosion of numbers of companies entering this field, and such firms are scrambling for geneticists, molecular biologists, and other specialists. In the early 1980s, a talented and well trained bioscientist who could qualify might command a starting salary of $35,000 to $40,000 a year. One marketing research firm estimated that there would be a high demand well into the 1990s. In an article on "Careers of the Future" (*The*

*Black Collegian,* August/September 1982) another research and development firm is quoted as saying that a person in this field—termed bioengineering—after four or five years of experience "can command pretty much what he or she wants." Further, the biotechnology explosion will see a great many undreamed of applications, and in the '80s and '90s will be at least comparable to the microchip revolution in the computer industry of the '70s. It should be understood that salaries in these brackets are available only to those who are thoroughly prepared. Part of this preparation would include several years of study beyond college, with a doctorate in the biological science, such as genetics, microbiology, molecular biology, and the like. This is a formidable and challenging prospect, but it should be remembered that for each job at such a level there would be a demand for supporting personnel. People with a baccalaureate or master's degree are also in demand at slightly lower salaries. Those who start at these levels can look forward to opportunities for further training on the job with appropriate advancement, or to obtaining credits toward a doctorate by studying while working. Some may wish to pursue such a course, while others will find a rewarding and satisfying career in the supportive role.

## GENETICS

In the above discussion of biotechnology, it is clear that application of the science of genetics offers many opportunities to make profound changes in the world in which we live. Indeed, a discussion of genetics must be in large part a continuation of the commentary on biotechnology, although there are aspects of genetics other than genetic engineering.

Simply defined, genetics is the science of heredity. Its pursuit involves observation of the superficial appearance of an animal or plant as related to its parents or its offspring; the inheritance of biochemical characteristics; the intimate nature of the structures in cells—especially the sex cells—which transmit heritable traits; and all other aspects of the complex mechanisms involved in heredity. The work which individual *geneticists* do varies from the solution of highly abstract and theoretical problems to the application of genetic principles to practical and economically important subjects. Any species of plant, animal, or microorganism may serve as objects for the geneticist's scrutiny. Much of what is known about cellular mechanisms involved in the transmission of traits

from one generation to another has been gathered from the study of relatively simple forms of life, such as bacteria and yeasts. The lowly fruitfly, *Drosophila,* has probably contributed more than any other animal to knowledge of the cellular structures known as chromosomes and genes which are involved in heredity. Among higher plants, probably more is known about the genetics of corn than of any other plant.

Human genetics has been widely studied, too, including hereditary traits, hereditary diseases, and the interrelationship between inherited characteristics and their modification by the environment. There are, however, many gaps in our knowledge. Much has been learned from the study of identical twins and their comparison with nonidentical (also known as fraternal) twins. Since identical twins develop from a single egg fertilized by a single sperm cell, they have the same genetic makeup. Nonidentical twins, on the other hand, are no more alike genetically than are ordinary brothers and sisters, since they develop from two eggs fertilized by two sperms.

Genetics has conferred many varied practical benefits upon mankind. The great hybrid corn industry, which has added millions of bushels to the annual crop of that important food, owes its existence to the study of the genetics of the corn plant. Developments in the genetics of crops, especially rice, have contributed greatly to the widely heralded "green revolution" which has increased the production of the staple food so important to the millions of people in the Far East. Perhaps further advances will lessen the dependence of these new varieties on the use of massive amounts of fertilizer.

The selective breeding which has produced superior strains of livestock is a practical application of genetics. The genetics of fur-bearing animals, especially the mink, also has been widely studied to the immense benefit of the profitable fur industry. Several years ago, a parasitic fly, the screw-worm fly, threatened to wipe out the cattle industry in Florida; the larva of this fly feeds upon the living tissues of cattle. Geneticists (and other biologists) virtually eliminated the fly from the entire cattle growing area by the simple expedient of releasing large numbers of male screw-worm flies which had been rendered sterile by radiation. Since the female screw-worm fly mates but once, a mating with a sterile male prevents the laying of fertile eggs. It does not necessarily follow that a similar treatment would eliminate all pests, but a study of the biology, including the mechanisms of heredity, of all species would contribute greatly to the solution of the problems which they present.

Opportunities for additional contributions of genetics are abundant. Further improvements in food crops and in breeds of domestic animals will help solve the food problems. Better knowlege of hereditary diseases is also needed. Genetic studies of endless variety are in progress. To present an additional example: in another section of this chapter mention is made of the devastating effects of the chestnut blight fungus upon one of our most valuable forest trees. Efforts are in progress through genetic experiments to select blight-resistant chestnut trees, so that possibly once more one of the glories of the American forest may be seen.

Although many advances in genetics have been possible by experiments in cross breeding of plants and animals, many opportunities are opening up in areas that owe their existence to the startling advances made by molecular biology. Information has accumulated in such volume and at such a rate that new agencies are being formed for the storage and subsequent retrieval of data in "gene banks." The units of heredity, the genes, are made up of only four units or molecules—adenine, cytosine, guanine and thymine, abbreviated as A, C, G, T, repeated over and over hundreds or thousands of times in varying sequence such as ACGTAGTCATGC . . . etc. The human genome, or the sum of all the genes in a single set of human chromosomes, is said to contain about three and a half *billion* such units. As the sequence of each new gene is determined, it can be compared with information already in the data bank.

Hundreds of biologists are employed in this research. In some instances, they have banded together to form new companies. Such companies maintain computer facilities which make programs commercially available. A lively competition has arisen in aiding researchers in analyzing their data and extracting information from it which would take years by any other means. The gene banks contain information not only about human genes, but many other organisms, including influenza viruses, animal tumor viruses, and human cancer cells. Every individual has a genome different from any other person; this difference is particularly important in our varying resistance to disease.

Some of the applications of genetics have aroused misgivings. Some people have expressed the fear, for example, that geneticists might inadvertently create new species of dangerous organisms. This problem has been discussed in conferences held by the scientists involved in such research, and they have agreed that they must act responsibly. In fact, there seems to be no indication that the worst fears expressed at the beginning of this research will be realized. Another source of unease is genetic

testing of employees by employers. Some genetic traits might make certain employees predisposed to illness when they are exposed to certain chemicals, for example. Others might suffer genetic damage from exposure, which could be detected by monitoring so genetic testing could possibly be used not only to screen prospective workers, but to detect any genetic changes after employment. Some have regarded this as an invasion of privacy, or as a possible means of discrimination if the practice is misused. However, the use of genetic testing is a growing practice, so employment opportunities for geneticists skilled in this area are increasing.

Industrial concerns employing geneticists also include pharmaceutical manufacturers, large producers of seed, especially hybrid seed corn, large producers of livestock and poultry, and large fur breeding farms. Government laboratories which employ geneticists include the Department of Agriculture, the Fish and Wildlife Service, the National Institutes of Health, and many others. Agricultural colleges employ not only theoretical geneticists but also those concerned with practical applications in the management of livestock, poultry, or crops. They usually spend part of their time teaching and part in carrying out research programs. Some universities have separate departments of genetics, but most of the employment opportunities in colleges and universities are in such departments as biology, botany, zoology, or microbiology.

From the above discussion, it is clear that genetics offers a variety of careers for those prepared to take advantage of the opportunities. A background of biology, chemistry, physics, mathematics, and computer technology would be helpful in giving the individual the widest choices.

## BIOMEDICAL ENGINEERING

Many exciting advances are being made in improvements in the care and rehabilitation of people who are handicapped because of the malfunction of some organ of the body that can be supported or even replaced by other organs or devices. Some of the more spectacular achievements in this field—such as a completely artificial heart—capture the public imagination and obtain much publicity. As interesting as such advances are, though, they actually represent only the tip of the iceberg of applications of new technology to human problems. Biomedical engineering is really a combination of medicine and engineering technology, and it is changing at such a rate that it is difficult to predict exactly what the career op-

portunities may be within the last decades of the twentieth century.

Some applications of advances in physics and engineering to biological and medical problems have been in use for several years; these include implanted pacemakers for the heart, devices which generate electrical impulses to initiate heart beats when the heart's own pacemaker falters. Artificial kidneys in the form of dialysis machines are prolonging many lives, but future technology will greatly improve and simplify the use of such devices. Advances are being made in the replacement of limbs by prostheses which respond to the body's own neuromuscular impulses. Visualization of internal organs without the intervention of X-rays is also becoming possible. At a still more sophisticated stage are research efforts toward development of artificial sense organs, including even eyes.

The number of career opportunities available in biomedical engineering is somewhat limited at present, but as research develops new applications of these technologies, more and more career opportunities will appear. One important center for research in this field is the Applied Physics Laboratory of Johns Hopkins University, and there it is felt that there is great promise for future expansion. Opportunities will exist not merely for research in this area, but for individual custom design, as well as for technicians skilled in maintenance and repair of the specialized devices.

## MICROBIOLOGY

The American Society for Microbiology was not exaggerating when it said, "microbiology is important from the core of the earth to the far reaches of outer space." Literally speaking, the world *microbiology* means the study of the very small—that is, organisms that can not be seen without the aid of a microscope. Microorganisms include bacteria, so *bacteriology* is a branch of microbiology. Many people think of bacteria as "disease germs" since so many infectious diseases are caused by bacteria. A closer look, however, reveals the fact that of about 1,500 known species of bacteria only about 100 cause disease. Many of the other 1,400 are of great importance to mankind and we could not exist without their activities.

Microorganisms, for all their tiny size and simple appearance, produce many complex substances. Some of their products are harmful, but more of them are such useful substances as vitamins and antibiotics. As we have noted above in the discussions of biotechnology and genetics, the numbers of such useful products can be greatly increased by manipulations which

include insertion of genes regulating specific chemical reactions within the bacterial cell. This is made possible by the fact that the structure of the DNA in a microorganism does not differ basically from that of the highest, largest, and most complex organisms. Some of the substances produced by microorganisms escape from the cells and produce profound changes in their environment. These include enzymes which convert complex materials into simple substances, helping in the disposal of waste and in making the materials available for re-entry into the cycle of life. They fix nitrogen from the air; higher plants as well as bacteria use bacterially fixed nitrogen for building body proteins. In this way, much of the protein in our bodies comes directly or indirectly from bacterial action.

Microorganisms can endure an astonishingly wide range of conditions, and some are adapted to live in temperatures far below freezing, while others exist in the boiling water of hot springs. They can be studied from the point of view of taxonomy, morphology, biochemistry, physiology, ecology, genetics, or any other aspect of living things, just as are higher plants and animals. Algae, fungi, yeasts, viruses, rickettsiae, and protozoa are among the kinds of organisms studied by microbiologists. Many of these appear to be simple forms of plant life, some cannot be readily classified as either plant or animal, while protozoa belong to the animal kingdom. A special branch of bioscience, *protozoology,* deals with the protozoa.

Probably few people realize how widespread protozoa are; they are found everywhere there is moisture—in soils, oceans, lakes, and in the bodies of larger animals. Some of them possess hard skeletons and are so numerous in the oceans that the skeletal remains form thick beds of deposits—the White Cliffs of Dover, for example. Protozoa are important in the ecological balance; they consume bacteria, they help convert wastes into materials utilizable by higher organisms, and they are themselves consumed as an important link in the food cycle. A special group of students of protozoa are *parasitologists.* A few protozoa are harmful parasites, producing such diseases as malaria, amoebic dysentery, sleeping sickness, certain venereal diseases, and others. Not all harmful parasites are protozoa, so many parasitologists devote their attention to larger parasitic creatures, such as round worms. Thus, a parasitologist may be partly *microbiologist* and partly *macrobiologist.*

The viruses defy simple classification as plants or animals; they are too small to be seen with an ordinary microscope or to be held back by bacteriological filters, but *virologists* have devised many ingenious ways of

studying them. Viruses have so many unique features that some virologists consider their specialty as a separate science and will hardly admit that virology is a branch of microbiology. Viruses are found in the cells of bacteria, plants and animals, and they may act as messengers, bringing in new genes. Some of the genes introduced into bacteria may alter the resistance to antibiotics. A single gene introduced into an animal cell may transform it into a cancer cell. Many plant diseases responsible for crop destruction are of viral origin.

Virologists are engaged in studying all these aspects of viruses, but some are trying to turn to mankind's advantage the predilection of viruses to invade animal cells and destroy them. Thus, viruses harmful to insects might replace toxic chemicals in sprays.

*Mycology* is a biological specialty which bridges the gap between microbiology and macrobiology. It is the study of fungi, which run the gamut in size from microscopic yeasts to huge puffball mushrooms. Mycology as a separate biological discipline will be discussed in the next section of this chapter.

Microbiologists contribute a great deal to the study of genetics, as we have seen in previous sections of this chapter. Some of these studies have produced new organisms, and the United States Supreme Court has ruled that such creations are patentable. Some strains of microorganisms appear to be especially sensitive to chemical compounds capable of inducing cancer. Such compounds cause mutations in the bacteria and this property makes it possible to detect potential carcinogens so that they can be removed from the environment.

Microbiology can boast some of the most illustrious names in the history of science and some of the greatest achievements for the benefit of mankind. Louis Pasteur, Robert Koch, Sir Alexander Fleming, and Jonas Salk are just a few of the great names that appear on the rolls of those who have contributed to microbiology. Within our century, a third of all the Nobel Prize awards in physiology and medicine have been bestowed upon microbiologists. Microbiology has so many practical applications that some microbiologists have complained that its value as a basic science has not been properly appreciated.

Microbiologists have been responsible for the development of vaccines, antiserums, and toxoids against a wide variety of diseases in man and animals. These include smallpox, typhoid fever, yellow fever, whooping cough, measles, influenza, and polio. Some microbiologists hope that some day the common cold, cancer, and others will be added to the list.

Many of our food and beverage products, including cheese, vinegar, wines and other alcoholic beverages, pickles, breads, olive and cabbage products, to name just a few, are dependent upon microorganisms, and microbiologists have contributed to the production and improvement of all of them. Microbiologists have also developed products for the preservation of meats, vegetables, and fish, and for the tenderizing of meats. Even the oil geologist utilizes microbiological information in his prospecting.

Diseases of animals are important targets of study by microbiologists. These include both the diseases which affect the animals and those which animals can pass along to humans. According to the World Health Organization, about 150 animal diseases are important in human medicine; such diseases, called *zoonoses,* include some such as brucellosis and bovine tuberculosis which have been conquered in most areas, but most of them remain to be controlled. In some areas of Africa, the cattle population could be doubled and the productivity of livestock markedly improved if just a single cattle disease—*trypanosomiasis*—could be controlled. Indeed, vast areas of the tropics have no domestic animals at all because of the presence of trypanasomes; and a few areas are virtually uninhabitable by humans for the same reason. So there is plenty of work left for the microbiologists of the future!

The branches of microbiology concerned with disease-producing organisms include *medical microbiology* and *veterinary microbiology.* Research on vaccines, antisera, and a variety of products of biological origin is performed by these scientists. They are also making strides in investigating the role of viruses in cancer. A host of problems related to public health, such as the spread of infectious agents by insects, rats, or other animals; the sanitary control of water and food; and the disposal of sewage are the domain of the *public health microbiologist. Agricultural microbiologists* are not only interested in diseases of plants and animals, but the wide range of their interests includes such problems as the growth of microorganisms for use as food for humans; yeasts and algae are among those suggested as possible future food sources. A hungry world is also awaiting the discovery of new organisms capable of extracting nitrogen from the atmosphere and turning it into a chemical form that can be used by plants. This can now be done by microorganisms in nodules on the roots of plants of the legume family; if a similar organism could fix atmospheric nitrogen for corn and wheat, for example, it would help solve the world's greatest food problem, namely, the need for high quality protein.

Microbiologists teach and do research in nearly all colleges and universities and in many professional schools, including those of medicine, dentistry, public health, nursing, pharmacy, veterinary medicine, and agriculture. Private research foundations, government research laboratories and service agencies, public health facilities, hospitals, and agricultural experiment stations employ large numbers of microbiologists. *Industrial microbiologists* are employed by the food, chemical, and pharmaceutical industries in large numbers. Some of these scientists are engaged in research, others in production, quality control, etc. The large scale production of antibiotics, steroids, and other complicated molecules can be done more effectively and economically by microorganisms than by the usual methods of synthetic chemistry in many instances.

Other industries which use the skills of microbiologists include wood products, paper, textiles, optical equipment, leather, and even electrical equipment. Their products are subject to microbial deterioration, and the microbiologist can forestall great economic losses by helping to control spoilage. In short, the man or woman trained in microbiology can have his or her choice of many careers. That training will involve basic courses in biology, chemistry, mathematics, and physics as pointed out in other sections of this book (see Chapter 3). Some colleges permit a major in microbiology; elective courses in microbiology and related subjects may vary depending upon the student's specific interest. If it is agricultural microbiology, the student will need botany and plant pathology, for example. If he or she is headed toward the chemical industries, a course in chemical engineering might be appropriate.

The top jobs in research and in university teaching will be held by those possessing doctoral degrees, as in most of the biosciences; but the variety of jobs available for microbiologists opens up many opportunities for those with baccalaureate degrees as well.

## MYCOLOGY

Mycology is a word derived from the Greek word for fungus, and a *mycologists* is a student of fungi. Perhaps the most familiar examples of fungi are mushrooms, but the fungi also include molds, mildews, yeasts, and the like. We are accustomed to think of all living organisms as belonging to either the plant or the animal kingdom, but the fungi have such

unique properties that some mycologists like to insist that fungi belong to neither of these, but constitute a kingdom of their own. Certainly, they do not have the ability of most plants to convert carbon dioxide and water into substances which supply energy to animals eating the plants. For this process to occur, the green pigment, chlorophyll, is necessary. No fungus has chlorophyll, although some fungi may live in close association with algae containing chlorophyll so that the combination appears to be one organism—a lichen. Like most bacteria and animals, fungi are obliged to live upon organic matter previously made by green plants. If they depend upon dead organic matter, they are called *saprophytes;* if upon living organisms, they are *parasites.*

The requirement for previously formed organic matter for food accounts in large measure for the immense practical importance which fungi have in the scheme of nature and in the economy of our civilization. Although a few of them cause disease in humans, the majority are of benefit. They take part in the breakdown of dead trees and other plants, helping to return the dead tissues to the soil and the air, thus completing the cycle of growth and decay. Without them, trees would not rot when they fall, and even the autumn leaves would become an intolerable burden. Some of these activities bring them into conflict with man, as when fungi destroy the wood of our ships or houses, or when they attack food crops growing in the field, or when they attach themselves to our skin to cause such diseases as athlete's foot—and other, more serious diseases. The control of such undesirable activities presents a challenge and opportunity for mycologists.

The useful products of fungal activity are many, and with genetic engineering the list is growing. Medically useful products include penicillin, streptomycin and other antibiotics, also steroids such as cortisone and the hormones of "the pill." Fungi turn milk into cheese and sugar into alcohol. They are abundant in the soil, on foods, in the air, on textiles and lumber—indeed, anywhere there is organic material and moisture. They are so widespread and their metabolic products are so useful that the discovery of new fungi is an important activity of some mycologists. The Mycological Society of America has estimated that there are over one hundred thousand different kinds of fungi known, and several hundred new ones are discovered each year. Many mycologists believe that there are more fungi and useful fungal products awaiting discovery than have yet been found.

Fungi and their products are being studied by many specialists in other

fields—chemists, molecular biologists, physicians, ecologists, pathologists, engineers, and many others. There are, then, many opportunities for collaboration between mycologists and others. Geneticists have learned much about heredity from studying the fungi, and cellular biologists and others have found much that is applicable to cancer research. In the applications of biology to forestry and agriculture, the mycologist collaborates closely with the plant pathologist, for the fungi are the chief cause of disease in higher plants.

The above description of mycology makes it apparent that there are many kinds of opportunities open for persons skilled in this field. The importance of mycology is becoming increasingly recognized, and many colleges and universities offer courses in mycology which did not do so a few years ago. These schools, of course, employ mycologists as teachers and research workers. Such professional schools as medicine, forestry, and agriculture also utilize the skills of mycologists. Medical research laboratories, whether in private research institutes, in the pharmaceutical industry, or in installations of the public health service, employ mycologists. In such institutions, fungi are studied not only as disease-producing agents, but many forms are cultivated and studied for their value in producing antibiotics and other medically useful products in ways that chemists cannot economically duplicate in the test tube. Industries and laboratories interested in food production, leather, textiles, and forestry products also have need of mycologists. Chemical manufacturers also seek to discover means of preventing spoilage of manufactured goods by devising and testing chemical substances that will control or kill fungal growth; mycologists are employed for testing such substances.

It should be pointed out that many of the positions mentioned above may also require knowledge of some field other than mycology and often only a narrow portion of mycological information is used in some particular job. For example, master bakers, vintners and brewers may know a great deal about yeasts, but not necessarily enough about other fungi to qualify as scientific mycologists. Other examples of application of a narrow spectrum of mycological information include pharmaceutical chemists who know all about fungi which produce antibiotics and other useful medicinal compounds. Relatively few of such specialists have a broad knowledge of mycology. Most *bona fide* mycologists belong to the Mycological Society, and a survey of the membership revealed the fact that about 87 per cent of the members are employed either in teaching and research positions in colleges and universities or in laboratories of state

and federal government. The Society points out that the mycologists with the broadest opportunities in industry also have some skills in other professions. For example, a mycologist with some knowledge of industrial chemistry would have doors open for more places than would someone trained in either field alone.

A mycologist should have first of all a base in biology in general, which in turn involves the basic sciences of mathematics, chemistry, including organic chemistry and biochemistry, and physics. Most mycologists begin to develop their interest in fungi when they are about half way through college, and the fully professional mycologist will obtain advanced degrees in graduate school. As pointed out above, however, there are many jobs available in specialized categories which do not require that one be a complete mycologists. If one does have both the special and the complete training, however, how many more opportunities will be available.

## SYSTEMATIC BIOLOGY

Systematic biology—also referred to as *systematics* or *biosystematics*—is a field that may have special appeal to those who enjoy orderliness and who like to be independent. Systematics may be defined as the study of the different kinds of organisms which exist, as well as the kinds which existed in the past which are now extinct. It includes not only a description and classification of organisms, but of the relationship between them, as well as the changes that have occurred in them during past generations. One aspect of systematics, *taxonomy,* studies the appearance and structure of a plant or animal, determines how it differs from others, describes its surroundings, classifies it in its proper place in the plant or animal kingdom, and names it. The aspect of systematics concerned with how organisms change over the course of generations, and what influences are at work on them is called *evolution;* that is, where does a given species come from? What processes are acting upon it to keep it as it is or to change it into something else? Can we predict what forms its future may take?

Systemists are not merely concerned with appearances; they use the tools supplied by other disciplines. For example, subtle differences in the structure of DNA from one species to another may give clues of their genetic relationships. The systematist may make original observations or use data supplied by other biologists, such as physiologists—the microscopic cell structure, the biochemical reactions taking place within living tissue, the

breeding behavior, the geographical relationships, the interplay between the organism and its environment, or any other data that may help to establish the position of the organism within the plant or animal kingdom.

Systematics is really a collection of many specialties, although there are a few *general systematists*. For example, a *mycologist* studies yeasts, molds, mushrooms or other fungi. A *dendrologist* specializes in trees, and an *algologist* concentrates on the small and simple green plants known as algae. An *entomologist* devotes his or her attention to insects, an *ornithologist* to birds, a *herpetologist* to reptiles and amphibians, an *ichthyologist* to the fishes, and a *mammologist* to mammals. It would be the exceptional student who deliberately chose to pursue one of these specialties before beginning the study of biology, but one's interest in a restricted field develops during the course of study. Indeed, there are few jobs specifically labelled herpetologist, ichthyologist, etc. Individuals with such specialized interests are *biologists* first of all, and they follow their specialty while teaching the usual biology courses. The American Society of Ichthyology has put it this way: "Nobody is ever hired merely to teach ichthyology . . . the young ichthyologist may . . . find that almost all of the available openings are for teachers of introductory courses like general biology." However, there are some exceptions to this. A limited number of openings for curators of ichthyology, or herpetology, or other specialties do occur from time to time—mainly in museums, zoos, aquariums, fisheries laboratories, and the like.

The glamor and importance of certain fields of experimental biology, including biotechnology and some of the biomedical sciences, may have overshadowed systematic biology in the eyes of many, but it is well that we recall the enormous contributions made by systematists to the quality of life which we enjoy. There is an urgent, and indeed critical, need for a thorough understanding of biological interrelationships if our civilization is to survive. In this respect, systematics interacts with and overlaps other biological disciplines, especially *ecology* and *genetics*. A few examples may be instructive.

During the present century, human life expectancy in many parts of the world has increased more than it had in all the thousands of years since the dawn of history. Our lives are not only longer but healthier. We are aware of the importance of medical research in this advance, but the contribution of systematic biologists to health and longevity is less well recognized. Taxonomists have studied and described harmful bacteria, plants, and animals; they have determined their relationships to other

organisms, including humans; they have described the position which each species occupies in the natural scheme of things (i.e., their ecological niche). Without the foundation of basic knowledge provided by systematic biologists, the great advances in health science and medicine for which we all are so grateful would have been immensely more difficult if not impossible. This is true not only in the study of organisms likely to cause disease, but also in promoting the discovery of antibiotics, and of improved sources of essential nutrients including vitamins and proteins. In the 1920s two systematic botanists spent two years in Asia. They spent $50,000 of American taxpayers' money, but brought back soybean types which now produce crops worth two-and-a half billion dollars annually to American farmers. Many plants and animals transported from one country to another prove to be valuable additions to the economy of the country into which they are introduced. Some of them, however, prove to be pests. An example of the latter is the prickly pear cactus in Australia. After it had ruined some 50 million acres of valuable grazing land, the help of the systematic biologist was sought in finding means on controlling the pest. An intensive study of all the information available on the prickly pear and on the plants and animals living in association with it revealed 160 different kinds of insects which were injurious to the cacti (50 of them were new to science). When some of these were introduced into Australia, one of them, a small moth from Uruguay, proved to be so damaging to the cacti that within seven years practically all the area formerly occupied by the prickly pear was reclaimed for grazing. This triumph for the systematists cost less than a million dollars, as compared to the estimated cost of eradication by spraying or by mechanical means of more than $500 million.

The outstanding success of American agriculture is based upon the introduction of plants and animals native to other countries. No major crop and only one important domestic animal—the turkey—is indigenous to the United States. A program of research on the systematics of species of potential economic importance is necessary if further useful introductions are to be made. Only by learning as much as possible about the biology of foreign species can a scientific prediction be made as to whether a new plant might be useful like the soybean, or a troublesome weed like crabgrass; whether a foreign fish might be desirable like the brown trout, or undesirable like the German carp; whether an introduced bird will make an honored place for itself like the ring-necked pheasant, or will become a nuisance like the starling.

There are many examples of introduced species that have become pests. Some of these introductions were made purposely but without adequate study of the relationships between the native and the exotic species. Others were made through accident or carelessness, often including no-longer-wanted pets. The numbers of such releases are astonishing; *annual* imports amount to more than 100 million fishes, more than half a million birds, and more than 100,000 mammals! There is an urgent need for better systematic knowledge of many groups involved in these imports.

Systematists have given valuable assistance to programs designed to encourage biological control of pests and diseases. They aid in ecological studies in many ways, such as identification of organisms in water to judge the degree to water pollution. Physicians and toxicologists in hospitals and public health laboratories employ systematists as consultants to aid in the identification of such toxic plants and animals as poisonous mushrooms and snakes. They participate in the discovery of plant strains resistant to disease. They identify fossil species of plants and animals in sedentary rocks as an essential part of oil and mineral prospecting. (Does it surprise you that oil companies employ systematic biologists?)

From all of these examples, you can see that there is scarcely any field of biology which offers such a wide variety of career opportunities. Systematics involves both field and laboratory work and deals with all manner of terrestrial and aquatic habitats. Systematic biology offers opportunity to travel both in the civilized and the wild parts of the earth. The systematist can also relate his professional interests to many other technical and academic fields, including such nonscience subjects as history, logic, and classical languages.

Systematists find employment as teachers in secondary schools, colleges, universities, and agricultural colleges. Museums, botanical gardens, arboretums, zoos, aquariums, private research foundations, and various local, state, and federal agencies employ systematic biologists. The federal government has been employing them since the time of the Lewis and Clark Expedition of 1803-04, and most of them are in the departments of Agriculture or Interior. Students in general have been so impressed with the "glamour" of research in the health sciences that relatively few have considered systematics as a potentially interesting and useful discipline. Now, when a number of important national and international research programs relative to our environment are under way, it is important that there should be no shortage of systematic biologists.

## ENTOMOLOGY

During past ages, various forms of life predominated at different times. For example, during the Jurassic period some 150 million years ago, reptiles dominated the land, and we speak of the Age of Reptiles or of the Dinosaur Age. In like manner, we may consider our own time to be the Age of Mammals, but in another sense it could just as well be termed the Age of Insects. More than three-fourths of all the species of animals in the world today are insects or their close relatives. From the point of view of mankind, many are pests spreading disease or competing for food or destroying desirable plants, while others are useful in pollinating trees, crops, and other plants or providing food for us or helping to destroy pest species. Whichever they do, insects affect the lives of every person. *Entomologists* are the biologists who study them.

Entomology overlaps with many other biological disciplines. Although the description and classification of insect forms have been going on for more than a century, and hundreds of thousands of insects have been described and named, the Entomological Society of America has estimated that there are large families of insects in which only about ten percent of all the species are known. The identification and classification of insects are fundamental to all other research in entomology.

Those biologists who study the intimate nature of the physiological and biochemical reactions taking place within cells or even at the molecular level find that insects provide an abundance of useful and interesting material. The *insect physiologist* makes discoveries that are useful in many areas—sometimes even in human medicine. An important part of research in entomology is the study of insect control; that is, research aimed at reducing or eliminating the harm done by insect pests. Contributions to these problems are made by those in both basic and applied research. The *economic entomologist* is especially concerned with reducing the damage done by insects to crops, forests, food in storage, and other interests of mankind.

In the past, most attention has been paid to insect control by means of poisonous chemicals, so the work of the entomologist has overlapped with that of the toxicologist. Now, many are interested in the use of chemical substances that are not systemic poisons—they might produce abnormal growth or behavior of the insects; they might attract insects to traps; or they might render insects sterile so they cannot reproduce. These goals are helped by research on the physiology, reproduction, and behavior of in-

sects; and the knowledge gained in this research is often of interest in other fields of animal and human biology.

Another avenue of approach to insect control is known as biological control. This involves the study of other insects or other forms of life which prey upon or destroy the insects we regard as pests, as well as the study of insect diseases—bacteria, viruses, or fungi which attract insects. The work of the entomologist thus may be closely linked with that of the microbiologist, the virologist, the mycologist, and so on. No form of life can be destroyed without affecting what is sometimes called the "balance of nature." Hence, the entomologist engaged in insect control will have occasion to collaborate with the ecologist and the wildlife biologist. One of the most interesting of the new developments in the biological control war against mosquitoes is a recent trial of dumping massive numbers of *Hydra* (tiny fresh water relatives of jellyfish) into mosquito-infested water. Hydra have a voracious appetite for mosquito larvae, and they don't chemically contaminate the water!

It would be difficult to mention a field of biology offering a greater variety of employment opportunities than entomology. Most teachers of entomology are hired by colleges and universities—especially colleges of agriculture and veterinary medicine. Industries which employ entomologists include producers and processors of food, the chemical industry interested in chemicals for insect control, and the lumber and pulp industries which utilize the skills of *forest entomologists.* We see constant reminders to help prevent forest fires, but few realize that insects destroy more timber each year than do forest fires.

The production and storage of food and fiber is of the utmost urgency for the expanding world population—now growing at a rate which doubles the population in about 35 years. Meeting this challenge would be greatly simplified if insect damage were eradicated, for it is estimated that fully one third of all production is destroyed by insects. Success or failure in controlling insects could well make the difference between starvation or survival in much of the world, especially the developing countries. Along with this, insect-borne diseases make life miserable for millions, and indeed there are areas at present uninhabitable or nearly so, which would be accessible if the insects could be controlled.

There are, then, tremendous challenges in entomological research, but application of research findings also offer many employment opportunities, and are of immense importance. For example, in agriculture, knowledge gained by the research scientist is transmitted by extension

workers to farmers. The research findings are also passed on to the next generation by teachers. The private sector also employs many people with skills in entomology. Major chemical companies employ entomologists skilled in toxicology and insect control. Although in the past mistakes have been made in the application of pesticides, there is growing realization that skilled personnel are greatly needed in devising and applying a balanced system of pest management. In addition to agricultural pests, there is a large industry in the United States engaged in control of termites and other pests which attack dwellings and other structures.

The demand for skills in control of pests is of such proportions that organizations within private industry have established offices where career information can be obtained. Their addresses are: National Agricultural Chemicals Association, 1155 15th St., N.W., Washington, D.C. 20005, and National Pest Control Association, 8150 Leesburg Pike, Vienna, VA 22180. Employment as a technician in pest control does not require a college degree, but for advancement some specialized education is needed, and both two-year associate degrees and four-year baccalaureate degrees in pest control may be obtained. Some of this training is available by correspondence; information about such courses may be obtained by writing to the addresses above.

Many entomologists are employed by state and federal governments in research laboratories and in biological survey work. Others are extension entomologists, helping farmers, growers, nursery workers, and householders wherever insects present problems in everyday living and commerce. Health agencies employ *medical entomologists*—that is, those specializing in insects responsible for the spread of disease. Agriculture experiment stations, plant inspection agencies, mosquito control boards, conservation agencies, and museums are a few of the other sources of employment opportunities. Several hundred inspectors are employed by the Animal and Plant Health Inspection Service of the U.S. Department of Agriculture to identify pests that hitchhike to the U.S.A. on imported animals and in tourists' pockets. These entomological inspectors perform an important and useful service. For example, inspectors have intercepted bark beetles that help spread Dutch elm disease and woodborers in crating and packing material, as well as fruit hidden in flight luggage containing larvae of fruit flies capable of threatening an entire industry such as citrus growing.

The largest organization of professional entomologists is the Entomological Society of America, with about 7,000 members, including

1,000 students. The Society not only encourages the highest standards among its members, and promotes communication of information, but it maintains a permanent office which answers inquiries about educational requirements and job opportunities. Such inquiries should be addressed to the Executive Director, Entomological Society of America, 4603 Calvert Road, College Park, MD 20740.

## MARINE AND AQUATIC BIOLOGY

Some biologists especially concern themselves with plants or animals which live in a watery environment. They may find fascination in a study of the classification, mode of life, functions, or adaptations of organisms inhabiting the sea—*marine biology*—or freshwater—*aquatic biology*. Few biologists will have interests broad enough to cover all these aspects thoroughly; one may be especially interested in the physiology of fishes, another in the systematics of marine algae, yet another in the structure or embryology of a particular group—for example, the minute invertebrate animals which form a part of the plankton (the small floating or swimming forms which are the basis of the food chain for all the larger creatures).

The economic importance of marine biology is being increasingly recognized. Most of us have read about the threat to the survival of mankind which has been posed by the often-mentioned "population explosion." For many years numerous observers have foreseen serious food shortages in widespread areas of the earth, and some have forecast worldwide famine. Recent reports from several regions have borne out some of these unhappy predictions. There is no question that population is increasing faster than agricultural production in the world as a whole. Marine biology may offer one bright spot in this gloomy picture. The knowledge provided by a study of sea creatures increased the world harvest of food from the sea at the rate of eight percent per year for many years. This is no longer true; perhaps we are reaching or approaching the limit of the food harvest available by fishing. Food from aquatic and marine organisms contributes protein, vitamins, and minerals to human nutrition—the very essentials which people in underdeveloped countries need the most. The need can be satisfied only by the results of continuing research efforts by marine and aquatic biologists.

The increase in world-wide consumption of fish is not only for human

food. Commercial livestock feeds and fertilizers demand an increasing share. The improved efficiency of fishing techniques has put great strains upon the ability of the sea to keep up. The American Fisheries Society recently stated that demands for fish products have threatened with irreversible depletion stocks of fish previously thought to be inexhaustible. Nor is this the only area presenting challenges to the fisheries biologist. The estuaries of large rivers and coastal marshes and wetlands form essential links in the chain. They are breeding areas for many species of fish, and of the smaller organisms which supply the fish with food.

Sport fishermen also are an important factor. The growth of recreational fishing is such that it is estimated that by the year 2000 some 63 million anglers will spend 1.3 billion days fishing! Both commercial and recreational activities are threatened by overexploitation and by deterioration in water quality.

Relying upon fishing to produce needed food is equivalent to the primitive "hunt and gather" method of prehistoric people. The aquatic equivalent to agriculture is *aquaculture*, and only through this procedure can we realize the full potentialities of aquatic organisms. Actually, aquaculture is not new; it is widely practiced in some countries. Indeed, a treatise on fish culture was written in China as long ago as 475 B.C., and four fifths of the world's aquaculture is still practiced in the Far East. Among the species of aquatic and marine animals widely cultivated are included several kinds of fish, such as salmon, trout, edible carp, catfish, oysters, and shrimp. Aquaculture has just begun to assume an important role in the U.S., as many large firms have entered the field. The fish produced by these methods in the U.S. more than doubled in the 1970s, and by 1982 amounted to more than 300 million pounds of food, but this still accounted for only 8 per cent of America's seafood consumption.

Energy conversion by water-dwelling animals is far more efficient than by land animals; that is, for each pound of food energy they consume, a greater portion of it is converted to meat suitable for human food. The explanation for this remarkable circumstances is two-fold: temperatures in the water environment do not fluctuate wildly as they do in the air; hence, aquatic organisms do not have to waste much energy in combating cold or in cooling their bodies during hot spells. In addition, the water they live in weighs nearly the same as does an equal volume of their own bodies; hence, they do not need to spend large amounts of energy for anti-gravity purposes.

For these reasons, the yields achieved in water far outstrip those on

land. Fertilized catfish ponds in the southern part of our country may yield as high as 4,500 pounds of fish per acre per year. This figure is dwarfed by the crops harvested from salt water. Some figures quoted by workers in ocean research laboratories range from 51,000 pounds of meat per acre annually in Japanese oyster beds to the fantastic figure of 268,000 pounds per acre per year in Spanish mussel colonies. To give some idea to the meaning of these figures: a good yield of small grain on a farm may be on the order of 100 bushels per acre. At 60 pounds per bushel, this would be about 6,000 pounds of grain per acre. When this is fed to animals for producing meat, it will yield about 600 pounds of unprocessed meat.

The full potentialties of aquaculture cannot be realized without the contributions to knowledge which only the biologist can supply. For example, the biosystematist could study the relationships of the species concerned and perhaps find useful species which are not yet used for food. The systematist would also be in a position to study the many lowly members of the food chain, to provide most effectively the food for the species being cultivated. The systematist could also supply information to aid the geneticist in selecting species for hybridization, and the geneticist would supervise selective breeding and hybridization. An active program of this type at the University of Washington in Seattle using rainbow trout as subjects has produced a breed of trout which grows to a weight of six to seven ounces. This new breed also tolerates water temperatures which the wild trout cannot endure.

Similar studies are also in progress with the valuable food fish, the salmon. The studies include the problems inherent in migratory and breeding habits of the anadromous fish; that is, those fish which live in the sea but spawn in freshwater. Considerable progress has already been made in the adaptation of aquaculture techniques to selected strains of such fish, but aquatic biologists are vigorously pursuing improvements. Subtle changes in temperature, salinity, and other properties of an aquatic environment can make great changes in its suitability for a given species.

There are many unsolved problems in aquaculture. For example, although oysters and shrimp are widely cultivated, experiments are needed on the genetics of these creatures. Techniques for growing lobster and abalone have recently been developed, but some companies have found attempts at cultivation of several species of seafood animals to be unprofitable, and some have given up attempts—others, however, are very successful. Thus, the need for additional research is apparent. Studies of the physiology of marine invertebrates need to be done. Such studies

would include nutrition and food supply for the animals under study, reproductive and endocrine physiology, the diseases which might threaten the venture, and all other aspects of their lives.

From this discussion, it is clear that there is plenty of work to be done by anybody choosing marine or aquatic biology for a career, and the potentialties for aid to mankind are great. Aquaculture, however, is only a special application of marine biology and is by no means the only source of career opportunities in these fields. Departments of oceanography in universities conduct studies in marine biology as well as in the chemistry, physics, and geology of the marine environment. The biologists in such departments are concerned with all aspects of the systematics, biochemistry, and physiology of plants and animals in water. Many departments of botany and zoology also employ biologists interested in aquatic and marine organisms. Institutions and agencies interested in the impact of society's pollution tendencies upon watery habitats also offer employment opportunities. These effects are often difficult to study because of the exceedingly complex effects of currents in bays, fjords, estuaries, as well as in the open sea and in streams. The biologist with a good foundation in mathematics and in computer technology is in a particularly good position to tackle these difficult problems.

Marine and aquatic biology offers a seemingly unending variety of occupations, and with advances in technology the list of possible careers expands. There are opportunities for outdoor occupations and a wide variety of indoor employment, or a mix of the two. To mention just a few of the openings that have been filled within recent years:

Monitoring salmon migration for a state agency
Inspection of fish handling aboard a processing vessel
Agent for the marine advisory service of NOOA (National Oceanic and Atmospheric Administration)
Analyzing water samples for culture of shellfish
Managing fish hatcheries
Surveying fish population
Supervising a fish farm
Investigating effects of volcanic eruptions on lakes and rivers
Preparation of environmental impact statements
Stream management for a private club

An especially active field in the 1980s with many job openings deals with the handling and processing of fish and shellfish for human consumption.

These openings require a knowledge of food science as well as marine biology. Workers in this field may be involved not only with the familiar food fish such as salmon and cod, but also with species available for food, but not much utilized—such forms as shark, squid, alewives, eels, to name a few.

Agencies of the U.S. Government which employ those trained in fisheries science include: Department of the Interior — U.S. Fish and Wildlife Service, Heritage Conservation and Recreation Service, Bureau of Reclamation; Department of Commerce — National Oceanic and Atmospheric Administration; Department of Agriculture — Farmers Home Administration, Forest Service, Soil Conservation Service; State Department — Bureau of Oceans and International Environmental and Scientific Affairs.

Some international agencies, such as the Food and Agriculture Organization of the United Nations, also employ marine biologists. Special laboratories devoted to research in marine and aquatic biology are located on the Atlantic, Pacific, and Gulf coasts and some are inland. A few are independent, such as the well-known Marine Biological Laboratories at Woods Hole, Massachusetts. Others are connected with universities, such as the Rosenthiel School of Marine and Atmospheric Science, University of Miami and the Scripps Institute of Oceanography of the University of California at San Diego, or the Laboratory of Limnology of the University of Wisconsin. Some university laboratories are located in close proximity with other agencies; for example, the College of Ocean and Fishery Science of the University of Washington in Seattle includes a School of Fisheries which offers undergraduate degrees in Fisheries Science or in Food Science. Nearby is a laboratory operated by the State Fisheries Department as well as the Northwest and Alaska Fisheries Center of the National Oceanic and Atmospheric Administration of the U.S. Department of Commerce.

These institutions and others like them offer careers to biologists primarily interested in research. In those supported by universities there are ample opportunities for teaching as well as for those who enjoy routine technical work, such as chemical analysis, plankton sampling, and the like. Some of these institutions support ocean-going research vessels—floating laboratories which range all over the world and which offer especially interesting opportunities for a limited number of biologists. Areas of research in marine biology make a long list; they may embrace ecology, water quality studies, culture of organisms for food for fishes as well as

culture of fish, physiology, pathology, and many other specialties.

The person considering marine or aquatic biology has a wide choice of colleges and universities where education and training can be obtained. Some schools offer undergraduate programs in fisheries science, but the American Fisheries Society emphasizes that before specializing, students should first obtain a thorough background in biology, including anatomy, microbiology, genetics and biochemistry. Mathematics, computer programming and statistics should also be included—and one must not forget communication skills, English, and the humanities. Sometimes there are opportunities for summer jobs, which not only provide valuable educational experience, but also will help the student decide whether this is a career he or she wishes to pursue. There are at least 126 colleges and universities offering courses related to fisheries sciences at the undergraduate level. They include such subjects as fisheries biology, fisheries management, freshwater biology, fish physiology, fish genetics, fish behavior, fish diseases, water quality management, and many others. Professional societies, such as the Sport Fishing Institute, and the American Fisheries Society, maintain lists of educational institutions offering such courses. Additional sources of information on colleges offering degrees in marine biology and related fields include the volumes mentioned at the end of Chapter 3, especially Volumes 3 and 4 of *The College Blue Book* (Macmillan) and the *Index of Majors* (College Entrance Examination Board).

Although the most challenging career opportunities in marine biology research are available primarily to those with advanced degrees, there are large numbers of positions open for those interested in practical applications. Several commentators have urged that the exploration of "inner space" of the earth's oceans be given a priority at least as great as the glamorous exploration of outer space such as the moon, planets, and beyond. As the importance of knowledge of the seas becomes more widely recognized, career opportunities in marine science, both biological and physical, will continue to increase.

## SOME SPECIALTIES IN PLANT SCIENCE

There are many varieties of botanists. They are the biologists who are especially interested in plants. *Plant systematists* or *taxonomists,* who have been discussed in a preceding section, describe, classify, and study the evolutionary interrelationships of the endless variety of members of the

plant kingdom. *Plant morphologists* are fascinated by the form and structure of plants, *plant ecologists* with their environmental relationships. There are no hard and fast lines between these various specialties. It is clear that the systematist, for example, must have an understanding of morphology and ecology. *Plant physiologists* are primarily concerned with the normal functioning and behavior of plants, how the plant absorbs energy and what it does with it, for example. The highly important problems of plant disease engage the attention of the *phytopathologist (or plant pathologist)*. Some botanists specialize in certain groups of plants; for example, the *bryologist* studies mosses and liverworts, and the *dendrologist* concentrates attention on trees.

Other plant scientists use their training in practical applications of their skills; they may become foresters, horticulturists, agricultural scientists, and the like. Careers in botany, then, may be quite varied. A few of them will be considered in the following sections of this chapter and in Chapter 6.

## PLANT PHYSIOLOGY

One could scarcely imagine a science of greater importance to humanity than *plant physiology*. This becomes apparent when one reflects upon the fact that all life upon earth, mankind included (with the exception of a very few unusual forms of bacteria), relies upon the sun as its ultimate source of energy, and that all animal life—including mankind—is utterly dependent upon the physiological activities of plants to convert the sun's energy into a form which suits our own needs. This is done, of course, by photosynthesis, the process by which the pigments of plants, especially chlorophyll, absorb the energy of the sun's rays and use this energy to convert carbon dioxide from the air and water from the soil into sugar. The sugar may then be converted into starch or fat or other substances, and with the addition of nitrogen from the soil into protein. The products of these reactions are the basic ingredients for all the metabolic processes of our own bodies—the processes which enable us to exist.

The increasing population of the earth will make continually greater demands upon our ability to control the growth and development of plants for improved food production; the plant physiologist is one of the key persons in this struggle. We need, for example, a more thorough understanding of the mechanism of photosynthesis, for the chemist still cannot

duplicate photosynthesis in the test tube. A large percentage of the efforts of plant physiologists is devoted to the study of plant metabolism, including photosynthesis, as well as the mechanisms by which the plant absorbs and transports water and minerals. A knowledge of the utilization of water by plants would be valuable in those parts of the world where water is a precious commodity in short supply. The increasing uses of water for industry in our own country and the resulting effects upon the reservoir of underground water stresses the importance of learning the role of plants in the overall cycle of water. More thorough knowledge of mineral metabolism in plants could help in learning how various plants adapt to soils of differing mineral content. And, of course, better understanding of photosynthesis might help immeasurably in increasing the manufacture of basic food substances; at the present time, *only* plants are able to make them.

Discoveries of plant physiology which have already been of value include the chemical substances—plant hormones—which regulate growth, cell division, and the differentiation of the various organs of the plant, such as roots, leaves, and flowers. Such knowledge has been useful in regulating flowering and the setting of fruit and in the destruction of weeds by the stimulation of abnormal overgrowth. The understanding of how these substances act is incomplete, and more needs to be known about them.

One expanding facet of plant physiology is that of *environmental physiology*. In the natural course of events, plant growth may be affected by salt in the air; salt water spray may affect the kinds of plants that thrive near the seashore. The effect is seen for a mile or more inland and even further during hurricane conditions. A comparable action is produced by salt placed on highways for ice control. The increased air pollution of recent years has exposed plants to gases and particulate matters for which they were not adapted, and there have been many instances of injuries to plants from these sources, both economic and aesthetic. The sources are: the burning of fossil fuels; incomplete combustion of coal or wood; and a great variety of industrial emissions. Injuries appear whenever a certain concentration is exceeded; different species of plants respond to different concentrations and exhibit different signs and symptoms. The identification of the trouble is a highly specialized field. In these studies, the plant physiologist, the plant pathologist, the ecologist, and the meteorologist cooperate with each other.

The solution to these unsolved problems relating to plant physiology will be sought by those plant physiologists who are engaged in basic research,

but there are also many involved in applying basic concepts to practical applications. About two-thirds of all plant physiologists work in universities, most dividing their time between teaching and research. The remainder are employed in government laboratories, in industry, or by private research foundations. The American Society of Plant Physiologists estimates that research in plant physiology is about equally divided between basic and applied. The plant physiologist interested in applied research finds many ways in which his chosen science is of practical benefit. If he or she is in industry, for example, the person may help to develop new chemicals or new ways of using chemicals for such things as controlling plant growth, increasing plant production, or destroying weeds.

The plant physiologist may deal with organic chemistry, physics, genetics, plant pathology, molecular biology, and other disciplines, but the job is to analyze and coordinate this knowledge. The plant physiologist may deal with a small part of the plant, but the ultimate goal is the understanding of the entire organism. It is no wonder that plant physiologists are found in all sections of the country, in every major university, and in all the agricultural research centers.

The education and training of plant physiologists do not differ markedly from those of other biologists during the undergraduate years. Although a basic understanding of biology is necessary, some plant physiologists have expressed the view that the physical sciences—mathematics, chemistry, and physics—are so important that physical science majors make good candidates for concentration on biological studies in graduate school leading to an advanced degree in plant physiology. There are, of course, many jobs in plants' physiology laboratories, greenhouses, etc., which do not require advanced degrees, but the top jobs usually are held by someone with a doctorate.

It may be seen that plant physiology forms a connecting link between basic biological research on the one hand and agriculture, forestry, and similar applied disciplines on the other. Biologists trained in this field will find a variety of outlets for their talents.

## PLANT PATHOLOGY

Closely allied to plant physiology is *plant pathology* (or phytopathology), which shares with its sister science the quality of being of supreme importance for the maintenance of our civilization. While the *plant physiologist* contributes discoveries which enable us to understand

plant growth, development, and behavior, with corresponding improvements in food production, the *plant pathologist* provides knowledge which enables us to control the plant diseases which continually threaten to wipe out all the gains made by agriculture, horticulture, forestry, and similar disciplines. The success or failure of the plant pathologist determines not only how well we eat, but whether we can survive.

Without the work of the plant pathologist there would be little wheat grown in the Middle West or the Pacific Northwest, nor would sugar cane plantations flourish in the South, nor sugar beets in Utah, nor potatoes in Maine. Our great fruit and vegetable industries would collapse. The threat of plant disease is not an idle one. Only a generation or so has passed since "rust" threatened to destroy the wheat growing industry of the U.S., and wheat rust still causes millions of dollars loss each year. The entire corn industry in the U.S. was threatened by blight as recently as 1970. A potato blight in the 1840s caused death by starvation of a quarter of a million people in Ireland and was largely responsible for the mass migration of Irishmen to America. One of the most beautiful and useful trees of the original American forest was the chestnut. Its fruit was a delicious nut; its wood was valuable for furniture and cabinetry; its growth beautified the landscape and even inspired poets. Within a couple of decades after the introduction of the chestnut blight fungus into this country, the American chestnut had almost completely disappeared. Many millions of our beautiful elms have been killed by the Dutch elm disease.

These few examples serve to illustrate how plant diseases continually threaten to cause critical shortages of food, fiber, and building material. The near miracles wrought by plant pathologists in the past have not abolished the threats, and there remain challenges as great as any that have previously been met. Plant diseases still cause billions of dollars in losses every year—fruits, grain, vegetables, flowers are attacked by bacteria, fungi, viruses, and other pathogens, as are animals. The tools which will be employed to meet these challenges will include the breeding of plants resistant to disease and the use of chemicals, including antibiotics and plant hormones, for combatting disease. The plant pathologist thus cooperates with the plant physiologist, the biochemists, and others.

The American Phytopathological Society estimates that there are more than 50,000 destructive plant diseases. This science is growing in importance and plant pathologists find employment in many diverse areas. Courses in plant pathology are offered in universities in every state in the Union and in Puerto Rico. Teachers trained in plant pathology are

employed in teaching such courses not only in departments of plant pathology but also in other biology departments, as well as in agricultural schools, in extension courses, and sometimes in secondary schools.

Research positions are available in state agricultural experiment stations as well as in the U.S. Department of Agriculture and in some other government departments, including the foreign service.

All major industrial firms engaged in the production of agricultural chemicals employ plant pathologists, and the federal government's program of technical aid to foreign nations engages many plant pathologists. Other phytopathologists work in conservation projects. These may be in wide open spaces, ranges, national parks, and forests, or in cities working with grasses, trees, flowers, and ornamental plants. Some are becoming "free-lancers"; that is, they go into private practice as consultants on plant disease or start up their own services for testing or disease control. They are doctors of plant disease, just as veterinarians are doctors of animal disease, or physicians are doctors of human disease. Their numbers are small, but growing.

There are positions in plant pathology for those with diverse levels of education. A baccalaureate degree in plant pathology is offered by some schools whose graduates find jobs with food processors, manufacturers of agricultural chemicals, and the like. They may also become federal or state plant inspectors, or they may teach in secondary schools or in two-year colleges. Those who continue their education through the doctorate will be equipped to handle the most challenging problems in the field and to qualify for the highest positions. The person who chooses plant pathology will be in a position to help humanity and all the animal kingdom in the process of helping the members of the plant kingdom.

## ECOLOGY

Until recently, ecology was a strange word to many people, but the rise in environmental consciousness has opened many doors for biologists interested in conservation and in protecting us from environmental damage. The study of the interaction between living things and their environment is not new but has recently assumed an importance in the popular mind not previously accorded to it. With the vastly increasing impact that mankind has had on the environment, it is important for our survival that we understand what we are doing to the world in which we live. It is en-

couraging that within recent years many people are becoming aware of the concepts of ecology, bearing out the prediction made in the late 1960s by Prince Bernhard of the Netherlands, who was President of the World Wildlife Fund when he predicted that ecology would become a household word to those who were then ignorant of its meaning.

It is difficult to understand what a latecomer mankind is upon the earth. Several years ago, Paul B. Sears, writing in *American Scientist,* pointed out that if the entire history of the earth were written in a book with each page recording a million years, we would have an immense volume of 4,000 pages. The beginnings of life would be recorded in the middle of the book, but man would not appear until the last page (recent discoveries indicate that this might be pushed back a page or two). The beginnings of agriculture would not be found until very nearly the end of the last line on the last page. If we think of what that means, we can see that the "rules of the game" or what we have called the "laws of nature" became fixed long before mankind appeared on the scene. And there is nothing to suggest that mankind is exempt from the operation of those laws. The future of our species depends upon maintaining a balanced harmony with nature.

## WILDLIFE BIOLOGY

The extinction of the dinosaurs was a very impressive event in geological history, but if we reflect that 1,000 species of dinosaurs became extinct over a period of a million years, we can see that on the average only one form disappeared in each 1,000 years. By contrast, man's activities have destroyed more than 200 species of birds and mammals within the past two or three centuries. Many others have been so drastically reduced in numbers that they may be doomed in spite of efforts to save them. It is not necessary to destroy the last member of a species in order to eliminate it, for there is a certain critical level below which a species fails to reproduce.

History is replete with examples, both ancient and modern, of adverse effects upon human culture when the principles of ecology are flaunted. The environment was able to absorb everything that we could do to it so long as technology was in a relatively primitive state and our numbers were not too great. But now it is threatened with a technology which includes even the potentiality of destroying all life and with an increase in the rate of population growth which, if not curbed, will render ineffective all other efforts at preservation of an environment in which most of us would like

Ecological Society of America has stated that the demand for ecologists will continue as long as environmental problems and issues persist.

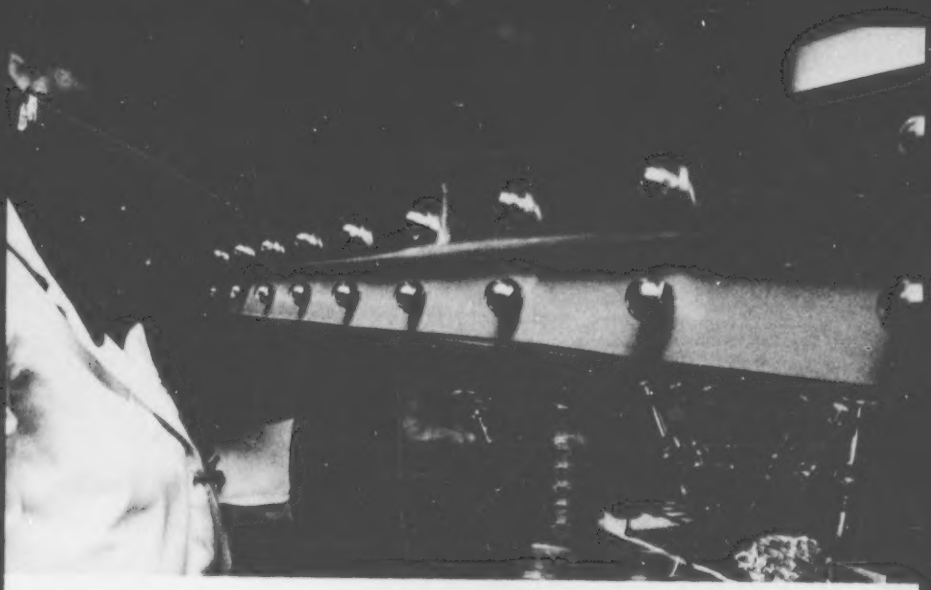
Although some ecologists are engaged in research, for many teaching is a basic function. Private industry and government use many ecologists as consultants. Consulting may involve practical application of the ecologist's special skills, involving interaction with people of many professions, including economists, lawyers, planning personnel, as well as other scientists. Biologists who become interested in ecology as a profession should have a thorough background in biology. A study of wildlife biology will usually be helpful. In addition to the usual courses in chemistry, physics, and mathematics which all biology majors should have, a study of soil science and geology is recommended.

Teachers who are oriented toward ecology may find employment in secondary schools as well as collegiate institutions. University departments which hire ecologists include the usual bioscience departments—biology, botany, zoology, and microbiology—and also specialized departments, such as forestry, fisheries, biology, horticulture, agronomy, entomology, oceanography, and wildlife management; there are also interdisciplinary programs. In the federal government the Forest Service, Soil Conservation Service, National Park Service, Fish and Wildlife Service, and U.S. Public Health Service are examples of agencies which utilize the skills of ecologists. The manufacturers of agricultural products, especially fertilizers and insecticides, hire ecologically oriented personnel, as do the members of the paper and oil industries where pollution is a problem. Several agencies of the United Nations have employed ecologists to gather data relating to the human environment in many parts of the world. Others have served as advisors.

From the above discussion, it should be clear that ecologists are vitally interested in conservation. Special careers in wildlife conservation are available. The *wildlife biologist* aids in the management of game, fish, fowl, fur bearing animals, or any type of wildlife. The biologist is interested in the habitats of all these animals, and may help in the preservation or restoration of streams, lakes, or marshes. Sometimes the work takes the wildlife biologist into remote areas, often under rugged and difficult field conditions. Other wildlife biologists may work in laboratories, concentrate on teaching, take part in extension work, or write or give lectures in their specialty. The research that wildlife biologists do may be related to taxonomy, physiology, genetics, and many other fields as applied to wild animals, fish, or birds. The research may be of a basic scien-

tific nature or have practical applications.

Most of the work of the wildlife biologist will be directed toward learning as much as possible about wild animals so as to preserve their existence and to lessen the impact of our civilization upon them. The biologist who chooses to devote his or her time and talents to ecology, conservation, and wildlife biology will be rewarded not only by a fascinating study, but by the knowledge that his or her future and that of mankind are intimately bound together. Ecologists and wildlife biologists are prominently involved in studies on the environmental aspects of the accelerating search for new sources of energy. Among their concerns are aid in the proper design, location, and operating methods of power plants, the effects of high voltage on wildlife, and the development of old mining land into a suitable habitat for wildlife. Whether you are of an idealistic or a practical nature, you may find these challenges to be rewarding.



Above, a research biologist prepares cultures for transfer within a biological safety cabinet. Below, a biologist uses a gamma counter to make quantitative measurements of proteins from cancer cells. Photos: Oak Ridge National Laboratory, photographer, Frank Hoffman.

CHAPTER 5

# CAREERS IN THE BIOMEDICAL SCIENCES

Biologists who choose to work in one of the biomedical sciences find themselves in the very forefront of advances in knowledge of health and disease, in factors governing aging, and in improvements in the physical and mental well-being of humanity. Nearly all medical advances have been based upon observations previously made in the laboratory of the bioscientist. The discoveries made in these laboratories have applications not only in medicine, but in many other fields of beneift to society.

## PHYSIOLOGY

In previous chapters we have pointed out that biology is not merely one science, but a group of sciences. No branch of biology illustrates this better than does *physiology*, which offers a rich variety of careers. Physiology is placed at this point in our discussion largely for the convenience of the author. You should understand that physiology is a broad term, embracing the interests of all life scientists whose primary concern is with the processes which sustain life. The present discussion will be confined to animal physiology (which includes, of course, human physiology); plant physiology has been considered in the preceding chapter.

The interests of physiologists are so varied that not only is it difficult to define physiology, but there is no clear-cut line separating it from closely related biosciences. It is usual to consider physiology as being the science concerned with the functions and operations of a living being or any of its parts, and of the interrelationship of one living part to another. One

leading physiologist has said, "Physiology . . . has contributed more than any other science to our present knowledge of the nature of man." More recently, another said, " . . . physiological sciences . . . have the greatest relevance of any field of science to the human condition."* Such statements are more than proud boasting. In a sense, all the biomedical sciences to be discussed in this chapter may be considered as branches of physiology, or they developed into independent disciplines from physiological origins but can still be considered to be part of the general category of physiological sciences.

Physiologists are concerned with such matters as: What makes animals (or people) grow? What regulates the rate at which they grow? How is food digested? What regulates the activities of the digestive tract and how can these activities be modified? How are the products of digestion absorbed into the blood stream, and then how are they distributed to places where they are needed? Why do we need blood and what governs its circulation? What are the intimate mechanisms involved in reproduction for the perpetuation of the species? How do people respond to changes in their environment? What are the physiological effects of pollution? What governs our responses to the day/night cycle or to the annual changes of the season? How do we respond to changes in air pressure such as those encountered in mountain climbing or in high altitude aviation?

These are only a few of the questions engaging the attention of physiologists; the list could go on and on. To find the answers, physiologists study living creatures, including man himself. The results of such inquiries form the very basic structure of medicine, whether human or veterinary. Scientists in related disciplines—such as biochemistry, pharmacology, biophysics, and psychology—must have a background of knowledge of physiology. Although the information gained by the study of animals most closely resembling man—that is, the mammals—has the most obvious application to human physiology, much has been learned from observations of creatures far removed from the human on the evolutionary scale.

A few examples will illustrate some of the things that have interested physiologists.

• One physiologist, for example, studied for many years the water balance in frogs; that is, the intake and output of water by the body of the animal. One might inquire: of what practical use is such activity? To the

*See "The Role of Physiology in Human Affairs," by M. B. Visscher, *The Physiologist*, Vol. 18 (February, 1975), pp. 19-30.

scientist such a question may seem irrelevant, and the experiments may have been done simply as a response to the need of the human mind *to know*. But in this instance, the simple experiments in the frogs were destined to lead in many directions. Other physiologists took up the study and discovered that the electrical and chemical forces involved in transporting water and salt through frog skin could also be involved in the functioning of nerve cells and the kidneys in human beings. These investigations, in turn, were eventually, after many further steps, put to practical use by physicians wishing to regulate kidney output in patients with certain kinds of heart disease. But that is not all. The knowledge gained in these studies has also proved to be invaluable in aiding people to cope with desert conditions; much use was made of it in the desert campaigns in North Africa during World War II.

- The migration and breeding cycles of migratory birds have long excited people's curiosity, and they still present many unsolved problems. It has been found that one factor in some of the cyclic behavior of birds is the length of day. Light, and a specific number of hours of light during a single day, perceived by the visual apparatus of the bird, triggers off the release of a chemical substance (a hormone) in a portion of the bird's brain called the hypothalamus. Cyclic behavior related to the time of year, and hence to length of day, is also characteristic of many other animals including some mammals. No one seems to know, however, whether a similar factor may be involved in the release of hormones in humans. Might this give a rational basis for the old adage, "In spring a young man's fancy turns to thoughts of love"? Do we interfere with the natural cycle of hormonal events by artificial lighting? We know that it is so in chickens, and poultry farmers take advantage of it.

- A physiologist studying the flight muscles of a housefly might be thought to be engaged in a line of research having little relevance to human medicine. However, a substance has been found in these tiny organs which is correlated with aging in the insect. With more and more people living into the retirement years, the processes involved in aging become of increasing importance. No one can predict to what heights basic discoveries may lead, no matter how humble a creature may be the subject of inquiry or how "far out" the question under investigation may seem to be. This is a point to keep in mind the next time you read of a scientist's investigation being held up for ridicule by someone ignorant of science, just because the title of the research does not have any obvious application to human problems.

Although there are some *general physiologists,* most physiologists specialize, and the list of specialties is a long one. The *cellular physiologist* studies processes that go on within the microscopic world of individual cells. The cells may range all the way from bacterial cells to those derived from human tissues, and information derived from one form often (though not always) applies to many others. In this way, laws are found that govern vital processes.

Other physiologists may become engrossed in the functioning of some particular organ of the body or a system of organs. For example, a physiologist who studies the endocrine system is an *endocrinologist;* her or his specialty is the system of glands which release secretions into the blood stream to be carried to other organs and assist in the regulation of growth, metabolism, reproduction, and many other processes. Even an endocrinologist may specialize and may study, for example, the reproductive system. Some physiologists study particular groups of animals such as insects, fishes, or even protozoa. The *comparative physiologist* is interested in those aspects in which one form differs from another; these findings are especially valuable to the veterinary physician as well as to the stock breeder or the pet fancier. You might find an exciting challenge as an *environmental physiologist* who can make direct and immediate contributions to our knowledge and awareness of the effect of society's changes in the environment, as well as of exposure to unusual stresses, such as certain tropical regions, the arctic, high altitudes, or space. It is not my intention to list all the kinds of physiologists there are, but merely to indicate by a few examples the surprising diversity available to you if you are considering physiological science.

The level of education you need as a physiologist depends largely upon what position in the physiological team you may assume. There are many openings for laboratory assistants and technicians; these will be discussed in a later chapter. Such positions may sometimes be entered directly from high school or perhaps with an associate in arts degree from a two-year college. However, for a more advanced position in physiology, a more prolonged education is necessary, and the top-notch jobs in physiology are held by those with Ph.D. or M.D. degrees. Colleges and universities employ about two-thirds of all physiologists. They are engaged in teaching, research, or both. Not all colleges have departments of physiology; at the undergraduate level of teaching, most physiologists have appointments in departments of biology, zoology, entomology, and the like. Agricultural and veterinary schools also employ physiologists. Medical schools are

especially important, for physiology is the very foundation of medicine, and physiologists are employed not only in departments of physiology and other basic sciences, but often in clinical departments—medicine, surgery—as well. Clinics, hospitals, private research foundations, drug companies, U.S. government laboratories and regulatory agencies—these and many others employ physiologists.

From time to time, the American Physiological Society surveys the educational institutions of the United States, Canada, and Mexico, and lists all those offering degrees in physiology. The growth of this bioscience may be illustrated by the fact that in 1965, the society could list only 16 colleges and universities offering a baccalaureate degree with a major in physiology. By 1974 this had grown to 31, but in the early 1980s more than 90 institutions offer such degrees, while about 200 are able to grant doctorate degrees in physiology.

It should be emphasized, however, that the future physiologist's choice of a college is by no means limited to one which offers an undergraduate major in physiology. Indeed, the majority of physiologists now at the height of their careers have specialized in physiology only in graduate school. A good background in biological science, however, is essential. This will include both general and advanced biology, physics, and general, organic, and physical chemistry. In recent years, the importance of mathematics has increased rapidly. Even laboratory assistants may need algebra in helping to plan experiments and analyze data, while the professional physiologist may need to understand calculus and probability theory not only to plan and interpret her or his own work, but to comprehend the work of others. If all of these courses are completed in the undergraduate years, the student will have a good background for specializing in physiology in graduate school. The student physiologist should also acquire some knowledge of related biomedical sciences, especially biochemistry and anatomy.

The boundary between physiology and some of the other biosciences is indistinct; indeed, the overlap is so great that an individual trained in one life science sometimes ends up working in another. For example, nobody can tell where physiology lets off and biochemistry begins. Physiology also overlaps with pharmacology, anatomy, genetics, embryology, parasitology, ecology, psychology, and other disciplines. For the convenience of the author as well as that of the reader, there must be some sort of classification; therefore, we shall proceed with a consideration of some related fields.

## BIOPHYSICS

*Biophysics* is one of the newest of the biological sciences, but it has grown rapidly. It is so closely related to physiology that in some schools biophysics and physiology are combined into one department. However, it has become sufficiently independent as a discipline for biophysicists to have organized their own society, The Biophysical Society.

The biophysicist's approach to biological problems utilizes the methods of modern physics, higher mathematics, and physical chemistry. The biophysicist addresses some very basic issues, and the findings often have practical consequences. Biophysics has contributed to the study of cancer; to the design of computer—which are analogous in some respects to the brain; and to the development of new drugs. Many biological problems cannot be approached without the aid of the instruments and methods of the physical sciences and even with the physical scientist's point of view.

All matter, living and nonliving, is made up of molecules, and the most complicated molecules in our bodies are the proteins. A protein molecule is made up of thousands of atoms, each arranged in precise order and spatial relation to each other. Most of the hormones of the body are proteins, as are the enzymes—those important "ferments" which enable our bodies to carry on complicated chemical reactions far beyond the abilities of the most brilliant chemist to duplicate in the test tube by usual chemical means. Biophysicists have contributed greatly to understanding the reactions involving enzymes. The outstanding advances in biotechnology, genetics, and biomedical engineering discussed in Chapter 4 were all made possible by the contributions of the biophysicist. Among these was the success in synthesizing the molecule of an enzyme associated with reactions involving RNA.

Many of the reactions within the cells of the body are those involving large and complicated protein molecules, which include among other things reactions in the immune mechanisms; that is, those mechanisms involved in defenses against foreign substances. The biomedical engineer has had some success in prolonging people's lives by replacing failing organs with transplants of healthy ones. These operations have been much heralded when they are successful, but there have been instances of disappointment and failure, often because of harmful interactions between the proteins of the transplanted organ and those of the patient receiving the transplant. In other words, the body of the recipient treats the transplant as a foreign and hostile intruder. There has been some success in avoidance of such in-

teractions, but there remains a large problem. Increased knowledge of interactions between proteins offers the most promising approach to the solution of such problems, and constitutes and important challenge which future biophysicists can help to meet.

Other interests of biophysicists include the effects of radiation on living matter, the details of the way in which the retina of the eye converts the energy of light into a signal to the brain, and the biological effects of gravity, of laser beams, and many others. Biophysicists have also contributed to the design and functioning of cardiac pacemakers—devices which initiate heartbeats in persons whose own natural pacemakers have ceased to function properly. All interactions of energy with living matter, whether animal or plant, interest the biophysicist. Hence, biophysicists seek to learn how plants convert the energy of sunlight into chemical energy which can be stored in the plant in the form of carbohydrate, which in turn supplies energy to our own bodies. Responses of plants to gravity (stems grow up and roots grow down) and the turning of plants toward a source of light are other examples of problems of the biophysicist whose answers might be not only of scientific interest but of practical importance.

From this brief description of biophysics, you can see that a biophysicist is a physiologist with a very special approach to physiological problems. The student aiming for a career in biophysics will need an extraordinarily broad base in physics, chemistry, mathematics, and biology, studying these disciplines in high school and continuing them through college and beyond to the doctorate. Some biophysicists recommend as many as ten courses in college mathematics. The student of biophysics will become familiar with the concepts of such subjects as protein chemistry, quantum mechanics, information theory, solid state physics, and probability theory.

Although the total number of openings for biophysicists may not be as great as for some other disciplines, the high degree of training required limits the number of competitors for the jobs available. Most biophysicists are employed by universities in teaching and research. Some are employed by the government in the laboratories of the National Institutes of Health, in space installations, and in the armed forces. Large hospitals, laboratories of non-profit research foundations, and drug companies also make use of the talents of biophysicists.

Biophysics is an intellectually demanding discipline to oe undertaken only by those who are willing to work hard and who enjoy mental stimulation. It is a highly experimental field, challenging and exciting, and utilizing the most modern concepts and instruments. If you have the basic

motivation for such a study and the capacity to meet the challenge, you will find it a most rewarding vocation.

## BIOCHEMISTRY

As the name implies, *biochemistry* is both a biological science and a branch of chemistry. It may be taught in departments of biology, physiology, or chemistry, but many universities have independent departments of biochemistry. Biochemistry is so closely allied with physiology that it would be difficult to make a statement about the difference between them without saying something that would bring an objection from either the physiologists or the biochemists. Perhaps it is fair to say that in most cases the difference is one of emphasis. Although the physiologist may use biochemical techniques to elucidate the function of a tissue or an organ, the biochemist will take special pleasure in studying the chemical processes that occur in active tissues. Both physiology and biochemistry evolved from general biology, but biochemistry could not arise until the advent of organic chemistry.

Considerable progress was made in physiology during the nineteenth century, but it was not until near the close of that century that chemists became aware that all organic substances contain carbon. The chemistry of carbon compounds then became organic chemistry. Biochemistry emerged as a separate discipline when some scientists combined biology and organic chemistry and began to study chemical reactions occurring in living systems. Biochemistry is hence a younger science than physiology and in a sense, may be regarded as the offspring of a marriage between physiology and chemistry. The lineage of biochemistry is apparent in the various names that are sometimes given to it: *physiological chemistry, biological chemistry,* and the like.

Biochemists spend their time in many different ways. Those with the highest degrees of education are usually involved in teaching or research, although a growing number may be in administration or in service work. Young people in the early stages of their careers are widely employed as laboratory workers, technicians, or assistants. Many find this type of work to be fully satisfying; advancement as a fully qualified professional research scientist, for example, does not appeal to everyone. The American Society of Biological Chemists, which is primarily interested in research, enrolls as members those deemed to be fully qualified professional

biochemists. The bylaws of the Society define "qualified" as someone who has "conducted and published meritorious original investigations in biological chemistry." The rapid growth of biochemistry as a scientific discipline is illustrated by the fact that even with this rather rigid qualification the membership of the society grew from about 3,700 to about 5,700 in the eight years from 1975 to 1983. It has been estimated that there may be at least twice that number outside the membership of the society. For example, those who are primarily employed in clinical laboratories in hospitals have their own society, the American Association of Clinical Chemists, which maintains a National Registry for clinical chemists and technologists.

Testing and analytical programs occupy the time of many biochemists, while others spend full time on research and still more are teachers; most teachers in colleges or universities devote part of their time to research. The research may be basic, that is, performed primarily to increase scientific knowledge; or applied, that is, to solve problems with immediate practical application. The research may be directed to such questions as: how do living things obtain energy from food? How do green plants convert carbon dioxide and water into carbohydrates with the aid of sunlight? How can we learn to imitate this process in the laboratory? What is the chemical basis of heredity? How do hormones work? What causes abnormalities? What fundamental changes occur in disease? What are the biochemical accompaniments of death? Can the changes in disease or death be modified so that health can be restored?

These are only samples of the many questions that biochemical research may seek to solve; there is scarcely any limit to the number of such questions that might be addressed. Many times the research biochemist or the clinical chemist must apply newly discovered techniques to her or his work. This may involve the use of new instruments or new chemical reagents. If existing methods and procedures do not fully meet requirements, the biochemist will need to invent them, test them fully in the laboratory, then publish the results so that other biochemists may confirm them. In addition to research and teaching, some biochemists, especially in hospital laboratories or in independent testing laboratories, provide services which assist physicians in diagnosing and treating disease. Others, especially those employed by industry, may also aid in quality control.

Colleges of pharmacy, dentistry, medicine, veterinary medicine, and agriculture are among the professional schools which provide opportunities for teaching or research in biochemistry. In these schools, it is not only the

departments of biochemistry which employ biochemists; employment is also offered in departments of physiology, pharmacology, microbiology, anatomy, medicine, and others. Departments of biology or chemistry in colleges and universities supply positions for many biochemists.

Hospitals, independent research institutes, public health departments, government laboratories, such as the famed National Institutes of Health, and agricultural experiment stations are among those who benefit from the special talents of biochemists. A wide variety of industrial laboratories, including food processors, drug and cosmetic manufacturers, and the huge chemical and petroleum industries constitute a continuing source of employment opportunities for those interested in applied biochemistry, in basic or applied research or in scientific administration. Many biochemists, especially clinical chemists, have gone into business for themselves, offering biochemical testing services on a fee or a contract basis. Such testing laboratories may employ numbers of biochemists, as well as biochemical laboratory assistants and technicians. The work load of testing laboratories, including those owned and operated by hospitals, has a record of growth; it is said that the load doubles about each seven years. This, then, constitutes a continually growing demand for those prepared to meet it.

The education needed by a biochemists will depend upon what position on the ladder the person wishes to take. For advancement to the top ranks, advanced degrees are desirable, and for the top-notch jobs, only a doctorate will suffice. Training leading to such degrees may usually be obtained while working as a laboratory assistant or teaching fellow. The education of the biochemist need not differ much from that of other specialists in the health sciences, but a good grasp of chemistry, mathematics, and physics is of special importance. Generally speaking, it is not necessary to major in biochemistry during the undergraduate years; most biochemists have majored either in biology or in chemistry, then concentrated on biochemistry in graduate school. About 200 colleges and universities offer graduate degrees in biochemistry.

Some biochemists have become interested in their specialty after attending medical school and receiving either an M.D. or Ph.D. degree. Biochemists with a medical background usually are employed in medical schools, hospitals, and research laboratories. By whatever route the biochemist enters the profession, he or she will find many opportunities for creative and exciting work.

## PHARMACOLOGY

Although pharmacology is a basic science which is an important part of the training of all students in all health professions, including pharmacy, medicine, dentistry, veterinary medicine, and the like, the word *pharmacology* is still not understood by many. Only within recent years has there been a move toward offering pharmacology at the undergraduate level in colleges of liberal arts, and the majority of schools do not have such programs. Most medical schools and many pharmacy schools offer courses leading to master's or doctor's degrees in pharmacology. The students who are accepted as candidates in these programs are usually graduates of colleges where they have majored in one of the biological sciences. The biology major should, therefore, become acquainted with the career potentialities offered by pharmacology. Young people trained in this discipline have had little difficulty getting jobs even during periods of recession.

To define pharmacology as briefly as possible, it is the study of the interactions of drugs with living systems. By "drug" we mean any chemical substance which can be given to a human or animal that will affect the recipient for good or ill or which will in any way affect the life processes. The living system might be a microscopic part of a cell, an organ of the body, or a whole animal or person, healthy or sick. Physiologists also study responses of cells, organs, and organisms, and biochemists study their chemical reactions. Pathologists examine the effects of disease. Pharmacology, then, overlaps with those disciplines and uses their techniques. No one could be a top-notch pharmacologist without a thorough background in physiology and biochemistry.

Physicians and pharmacists also know a great deal about drugs, but to be a physician or a pharmacist is not necessarily to be a pharmacologist. The pharmacologist's knowledge of drugs is unique. The intimate nature of drug action as affected by the size of the dose, method of administration, solubility in various body fluids, the effects of small changes in chemical structure of the drug, and the significance of physical properties as related to drug action are among the matters of concern to the pharmacologist but outside the specific interests of physiologists or biochemists.

Pharmacology is divided into many branches as are most other life sciences. The *general pharmacologist* tries to understand the action of a drug in all parts of the body and often is searching for better and safer

drugs for treating disease. The interests and methods of the *comparative pharmacologist* might be similar and his findings might be of interest, for example, to a veterinary physician who needs to treat various species of animals. *Molecular pharmacology* is more basic in its approach and seeks to discern the interaction between a molecule of a drug and a molecule within a cell of the body. Some of the discoveries of the molecular pharmacologists have given physicians valuable information about such things as the intimate mechanisms of the nervous system or the actions of the kidneys. *Biochemical pharmacologists* or *biophysical pharmacologists* use the techniques of physics and biochemistry; sometimes their primary interest is to determine what the body does to the drug rather than what the drug does to the body. Such information is especially valuable in helping to improve the drugs already available.

*Toxicology* is a branch of pharmacology specifically concerned with the adverse effects of chemical substances, ranging all the way from minor unwanted effects of useful drugs to the actions of virulent poisons. The toxicologist is equally interested in the immediate effects of a single exposure to a substance and the long range actions of a drug that a person may need to take daily for many years. Toxicologists are in great demand in the drug industry. No drug is 100 per cent safe; one of the duties of the *medical toxicologist* is to determine the limits of safety of a drug. One would hope to find out enough so that we could never again have a tragic occurrence such as the armless babies who were born of mothers taking thalidomide. The *industrial toxicologist* applies his knowledge to the health of workers in industry; a wide variety of industrial concerns utilize such expertise. The *environmental toxicologist* helps protect public health by studying the effects of water and air pollutants, industrial wastes, household chemicals, food additives, pesticides, and the many other exposures of the modern world.

Some pharmacologists concentrate their studies upon some particular organ or system in the body. For example, the action of drugs upon the nervous system comes under the attention of the *neuropharmacologist*. His interests are related to those of the *psychopharmacologist* who uses the techniques of psychology to ascertain the effects of chemical substances upon behavior and psychic functions. These branches of pharmacology have become especially important since the use of drugs which alter behavior has become so widespread.

Deserving of special attention is the *clinical pharmacologist* who applies the discoveries of other pharmacologists to the human subject and who, of

course, also makes many discoveries. Clinical pharmacologists seek to determine whether a particular drug is useful, how it should be used, and what adverse effects it may have. They bridge the gap between the original discovery of a new drug and its use by a practicing physician. They must, therefore, be versed not only in physiology, biochemistry, and pharmacology but in medicine as well. They possess M.D. degrees, and sometimes Ph.D.s also. The training of a clinical pharmacologist is a long one, and this specialty is one of the most important and demanding of all the health sciences.

Employment opportunities in pharmacology are available in medical, pharmacy, and veterinary schools—and to an increasing extent in four-year colleges. Pharmacologists are also in demand in government laboratories, especially such agencies as the National Institutes of Health and the Food and Drug Administration. Hospitals and independent nonprofit research laboratories hire many pharmacologists, as do the laboratories of industry, especially the pharmaceutical industry. Several independent laboratories engaged in providing service to other institutions under contract also hire pharmacologists. The variety of activities in which pharmacologists are engaged matches the variety of institutions for which they work. Some spend most of their time teaching, some are in basic research, some are engaged in trying to discover new and better drugs for the treatment of human or animal diseases, others help in the protection of public health and safety.

There are many opportunities for working in a pharmacology laboratory for those without complete professional training, but for the top level jobs a doctoral degree is essential. During the high school and undergraduate college years, the education of a future pharmacologist parallels that of a physiologist or biochemist. Most helpful will be courses in mathematics through calculus including statistics; a course in general physics; and chemistry, including organic and physical chemistry. With such a background, whether or not the curriculum includes an undergraduate course in pharmacology, the student will be well equipped to pursue graduate study in most of the basic medical sciences, and need not make a final choice among them until graduate school.

## NUTRITION

There are several biosciences concerned with food and nutrition in one

way or another. We have already seen that physiology and biochemistry may deal with digestion and assimilation of food and with the distribution and disposition of the products of digestion after they are absorbed into the blood stream. In the next chapter we shall comment on careers in food technology. Nutrition overlaps those disciplines but it may also be considered a bioscience in its own right. The *nutritionist* studies the fate of foodstuffs after digestion and absorption (thus overlapping with physiology and biochemistry), and is especially concerned with the relationship of food to the health and welfare of both the individual and society, and its connection with the cause, treatment, or prevention of disease.

There should be no doubt about the importance of a knowledge of nutrition so long as we live in a world in which much of the population goes to bed every night with unfilled or partially filled stomachs. We have all heard of the catastrophic effects on population in the past by diseases having their roots in nutritional deficiencies; for example, the huge losses of manpower from scurvy during the days of the old sailing vessels before ships were provisioned with lemon juice. Scurvy was mainly caused by a lack of Vitamin C; but it would be incorrect to think that deficiency diseases are a thing of the past. An example is *kwashiorkor,* caused by a protein deficiency and prevalent today in much of the underdeveloped world. The victims are mainly children between the ages of six months and three years who simply cannot eat enough to fulfill their protein requirement with the type of diet that prevails where they live. A publication by the World Health Organization states, "From the public health point of view, these children are the greatest problem in the world today." Nutritional deficiencies are not unknown in impoverished areas, both urban and rural, in our own country.

Many groups, such as the Food and Agricultural Organization of the United Nations, as well as individual nations, industries, and independent research organizations, are seeking ways to correct these conditions. Those with training and skill in the science of nutrition will find useful and rewarding work in these areas. In our own society, although we know how to prevent such diseases as scurvy, pellagra, and beri beri, research is still under way on the nutritional aspects of hypertension, heart ailments, obesity, tooth decay, and possibly even arthritis and cancer. Some unfortunate children are born with errors in metabolism of foodstuffs which lead to mental retardation and early death; an example of this is the disease known as phenylketonuria. Largely because of the efforts of nutritionists, many of these children have been able to develop in a nearly nor-

mal fashion, and research is continuing.

Some nutritional discoveries have far-reaching results. I can remember when a diagnosis of pernicious anemia was almost the same as a death warrant. With the discovery of vitamin $B_{12}$, the means for treating this disease was at hand. But $B_{12}$ was to have an unexpected and quite unrelated significance in nutrition, for it proved to be a factor which increased the efficiency with which meat animals converted hay and grain into body-building protein.

There are several types of careers related to nutrition. ***Research nutritionists*** are scientists contributing new knowledge relating to human or animal metabolism, the interrelationships of foods, the effects of nutrients on health, and the like. They are employed in universities; in medical, dental, veterinary, and agricultural colleges; in government agencies; in international agencies; and in industry, especially industrial concerns engaged in supplying dietary supplements for either human or animal use. ***Public health nutritionists*** apply the science of nutrition in various fields of health care and are primarily employed by private or public health agencies concerned with health care. Other nutritionists are primarily engaged as teachers. *Dieticians* apply the principles of nutrition in the planning and management of food service programs in hospitals, schools, and other institutions. Some dieticians prescribe diets, select foods, and counsel hospitals, clinics, and other individuals or communities; they are *clinical* or *therapeutic dieticians.*

The wide range of different kinds of jobs in nutrition is reflected in the range of educational requirements. The American Dietetic Association maintains a list of colleges which provide training courses for high school graduates to qualify as *dietetic assistants* or *dietetic technicians;* these courses may lead to an associate degree. There are also undergraduate programs leading to a baccalaureate degree as a dietician; other graduates may become approved dieticians after a suitable internship. In many states, there are universities offering advanced training to the master's and doctoral levels also. The education and training of the *research nutritionist* is comparable to that of other bioscientists. Biology courses, including physiology, microbiology, and physical science—including organic chemistry and biochemistry—are essential. Mathematics and physics should not be neglected. As in all sciences, the research nutritionist with a doctoral degree has an advantage.

Nutrition offers career potentialities for both men and women, and there are few professions in which these opportunities are more nearly equal.

## IMMUNOLOGY

*Immunology* is the study of the way in which the body protects itself against foreign invaders, whether it be a substance producing an allergic reaction, an invasion by disease-producing microbes, an organ transplant, a parasite, or a virus. The reaction of the body to each of these insults is called an *immune response.* Each immune response is very specific; that is, each particular kind of invader produces an immune response that is specifically directed toward that invading material. The invading stimulus is a chemical substance (called an antigen) and the body produces another chemical substance (antibody) which reacts chemically with it. Hence, immunology could be considered from one point of view to be a branch of biochemistry. Since the immune system is one of the normally functioning systems of the body, immunology is also a branch of physiology. Since an immune response is often a part of a disease process, immunology is to some degree a part of the science of pathology. And since immune responses sometimes have to be treated by physicians, immunology is also a part of medicine.

Immunology, then, is another example of the overlap among biomedical sciences that we have mentioned in previous pages. It is, however, a science in its own right, and professional immunologists have their own society, the American Association of Immunologists. Some of the triumphs of immunological research have been of inestimable value to society, and the potentialities for future developments form an exciting prospect. No doubt you have heard the story of the eighteenth century English physician, Edward Jenner, who noticed that dairy workers who had had cowpax—a relatively mild disease—did not thereafter get smallpox—a serious and often fatal disease which was then prevalent. Dr. Jenner was then able to protect others by deliberately infecting them with cowpox.

Less familiar is the story of the great French bacteriologist, Pasteur, who through an oversight (even the greatest of scientists make mistakes) left a dish on the laboratory shelf while he went on vacation. The dish contained bacteria which could cause cholera in chickens. But the conditions to which the bacteria were exposed rendered them incapable of causing disease. Instead of dumping them down the sink, Pasteur experimented further with them and found that chickens receiving them were protected against cholera. From this beginning, he made many other vaccines. Today we have many vaccines, useful against many diseases which formerly killed millions of people each year but which now are seldom seen in most parts

of the world. The ability of a great scientist to turn a mistake into a brilliant discovery has been shown more than once in the history of bioscience—the story of Alexander Fleming and the discovery of penicillin has been mentioned in a previous chapter.

Diseases caused by bacteria and viruses are not the only things that excite the interest of immunologists. If you suffer from hay fever, if you have symptoms like a common cold when you breathe house dust or animal danders, if you have a severe rash after contact with poison ivy, if insect stings cause severe reactions, then you are experiencing an immune response which, instead of protecting you, is causing you distress. Some people even develop such responses to some of their own cells or tissues—these are called "autoimmune disease"; perhaps the most common of these is rheumatoid arthritis, which makes millions of people suffer. All of these furnish challenges to the immunologist, who seeks knowledge which will enable physicians to alleviate the symptoms of such disease—and in the end, cure or prevent them.

Other challenges for the future of immunology include the control of adverse reactions in blood transfusions and in the transplantation of tissues and organs. Of the many thousands of kidney transplants that have been made, hundreds have been failures, and immune responses have been the cause of as many failures as all other causes combined. Especially exciting are the prospects for possible immunological treatment of cancer; or for the selective removal from the blood of troublesome substances which trigger immune responses; or for reducing the risks from those responses which are inherited. No wonder that the National Institute of Allergy and Infectious Diseases of the National Institutes of Health has referred to immunology as "a discipline whose time has come."

Recent advances in biotechnology have given immunologists new tools to use in their research. Substances known as monoclonal antibodies are produced by hybridoma, a special type of cell created by fusing two different kinds of cells. The interests of immunologists thus overlap those of geneticists, microbiologists and bioengineers, as discussed in Chapter 4, and any distinction between immunology as a basic science and as a practical discipline must be arbitrary—as indeed is the case with all the biomedical sciences.

Immunology presents career opportunities ranging all the way from laboratory assistants and technicians to professional scientists in charge of large laboratories. At all levels, the work is of absorbing interest and gives great personal satisfaction. The worker in immunology uses many of the

laboratory techniques of biochemistry and microbiology. The better the person's preparation in these fields, the better he or she will be able to perform the duties, and the greater pleasure the worker will derive from the daily activities. For full professional standing and the best rated jobs, the undergraduate preparation should be about the same as we have described for the other biomedical sciences—namely, a grasp of biology, including microbiology, with chemistry through organic and preferably physical chemistry, a course in physics, and of course, a basic understanding of mathematics.

About half of the professional immunoiogists who have qualified for membership in the American Association of Immunologists have received the Ph.D. degree, a smaller number the M.D., a few have both degrees, and a very few have been admitted to membership without a doctoral degree. Immunologists who have not yet qualified for membership are, however, welcome at meetings and are encouraged to present papers describing their research.

Immunologists employed by educational institutions divide their time between teaching and research; this includes more than half of all members of the profession. Training in immunology may be obtained in almost any university having a medical school, and there are a few immunologists in departments of biology. There are relatively few departments of immunology; most often it is a section within a department. Departments of microbiology, biochemistry, and medicine most frequently employ immunologists. A few hospitals and research foundations also give employment to immunologists, but the leading employer outside the medical schools is the federal government, especially the National Institutes of Health. There are also some openings in laboratories supported by local and state governments.

In opportunities to be on the frontier of science, no discipline surpasses immunology.

## PATHOLOGY

*Pathology* is both a basic biomedical science and a specialty of medicine. By the use of the techniques of biology, chemistry, and physics, pathologists examine the tissues and fluids of the body. They seek to determine the presence of any measurable or visible changes produced by disease or by any other interference with normal bodily structure or func-

Biologists scan for genetic damage in the offspring of insects treated with effluent materials from a coal conversion process. Photo: Oak Ridge National Laboratory, photographer, Frank Hoffman.

tion. *Plant pathologists* were discussed in Chapter 4; in this section, we shall be concerned with those pathologists who examine specimens of human or animal origin. Their findings enable them to judge whether a given specimen has come from a healthy individual or if there is disease or injury. The nature of a disease and the effectiveness of treatment may also be revealed.

Pathology, then, is a link between the basic biomedical sciences and clinical medicine. Most pathologists are physicians who have specialized in this particular field. Medicine and its specialties are beyond the scope of this book, but we are interested in pathology as a biological science. A career booklet issued by the Intersociety Committee on Pathology Information does not discuss the possibility of a career as a professional pathologist except as a specialty for the physician with an M.D. degree. However, there is a demand for pathologists who are not physicians. In the latter category are dental and veterinary pathologists as well as a growing number in research and service jobs who have a Ph.D. in pathology. In fact, many of the members of the American Society for Experimental Pathology have advanced work in areas other than that for the M.D. degree.

In addition to the top-grade professional jobs, there is a demand for workers in pathology laboratories especially trained for the many demanding technical jobs. These laboratory technicians and medical technologists will be discussed in the next chapter, but we should mention at this point that the demand for such workers is very great. Physicians are placing more and more reliance on the findings of the laboratory to assist them in diagnosing disease and in following the progress of therapy. Some of the laboratory jobs also give an opportunity for the young worker to study for the most advanced professional qualifications.

Some diseases can be identified only by laboratory means, e.g., diabetes and leukemia. The pathologist is not only essential for the diagnosis of such diseases, but also supplies the means for following responses of the patient to treatment. For supervising a laboratory bearing such important responsibilities, a pathologist should qualify for a special certificate from the American Board of Pathology. In most cases, the pathologist will also be a teacher, aiding in the training of medical students, nurses, interns, medical technologists, and resident physicians.

Teaching, research, and service—these are the outlets for the pathologist's skills. Nearly every accredited hospital employs pathologists. A pathology department is a prominent feature in medical schools; dental

and veterinary schools also have such departments. Some pathologists operate independent laboratories which provide service to physicians in private practice. Independent research institutions operated by nonprofit foundations employ many pathologists and pathology technologists. A particularly important source of employment opportunities is the federal government, as well as state and local public health installations. The armed services operate large institutes for research and service in pathology, and the famed National Institutes of Health and the Food and Drug Administration have particular need for those with skills in pathology

Laboratories concerned with studies on the safety of drugs provide a large and expanding demand. Individuals with Ph.D. degrees in pathology, or with training in veterinary pathology, are especially in demand in these establishments. Studies on the safety of new drugs must be conducted at length and with great skill on experimental animals before the drug can be tried on humans. After the animals have received the new drug, the fluids and tissues of their bodies must be subjected to the same tests as those made on human patients in disease. In fact, no patient ever gets quite as thorough an examination as do these animals. Federal laws and regulations make such studies mandatory, and the standards are constantly being elevated; hence, the demand for personnel is very great.

The tests just described are performed in the laboratories of drug manufacturers and in many laboratories operated by the government, such as the National Institutes of Health and the Food and Drug Administration. In addition, many independent laboratories carry out similar studies. Several commercial pathology laboratories perform such tests for others on a contract basis.

Above, a biologist working in recombinant DNA research in an insulin production project, Eli Lilly and Company. Below, SCS scientists map soil for a survey in the District of Columbia. Photo: USDA—Soil Conservation Service, photographer, H.E. Alexander.

CHAPTER 6

# OTHER CAREER OPPORTUNITIES IN APPLIED BIOLOGY

## THE AGRICULTURAL SCIENCES

The application of biological and physical sciences to the production of food and fiber forms the very foundation of the success of our civilization. It has helped to make American output levels the envy of the world. It is no wonder, then, that an extraordinarily large and varied number of careers can be found in these fields. The *Occupational Outlook Handbook* of the Bureau of Labor Statistics, U.S. Department of Labor, lumps biological scientists and agricultural scientists together and estimates that in the early 1980s these sciences give employment to about 125,000 people. Nearly a third of these can be classed as agricultural scientists.

Agricultural scientists come from a wide variety of training programs and engage in many different kinds of work. Some of them have already been discussed; such disciplines as plant pathology, entomology, ecology, fisheries biology, and genetics are among those described in previous chapters that have applications here. Examples of agricultural sciences which may be regarded as applied biology include the following: *agronomy,* which applies biological science to crop breeding and production, the testing of new varieties of plants, plant propogation, and so on. *Horticulture* is a related field, embracing not only breeding and culture of plants, but problems in storing and handling. Ornamental as well as food plants are considered. *Forestry* is a related discipline; more about forestry

will be given in a following section of this chapter.

Among the animal sciences which should be considered are *animal husbandry*, concerned with the breeding, nutrition, and overall quality of livestock; *poultry science* and *dairy science* are sometimes considered as separate branches of animal husbandry.

*Soil scientists* are interested in the biological effects of soils as affected by physical, chemical, and other properties. *Food technology* applies science to the production, processing, preparation, and distribution of food. For example, such familiar items as freeze-dried coffee, frozen orange juice concentrate, and dehydrated vegetables are the results of the efforts of food technologists—as are the packaging innovations which permit them to be marketed. The food technologist must know something of nutrition, physiology, biochemistry, microbiology, and related sciences.

A highly developed specialty is that of *seed technologist*. Seed technology, a surprisingly wide-ranging field, has a place for people trained in botany, genetics, agronomy, entomology, and several other specialties. The seed technologist and seed analyst may supervise harvesting procedures of seeds, conduct tests for purity and germination, evaluate storage procedures, devise methods for control of insects and fungal infestations, and many other procedures. Research in the field may be concerned with breeding improved varieties, increasing seed yield, and improving processes involved in the handling and distribution of seeds. Special problems and opportunities may be presented by the introduction of new varieties resulting from genetic research (see Chapter 4) and the seed technologist keeps abreast of these developments.

It has been estimated that there are about 350,000 species of plants capable of converting solar energy, carbon dioxide from the air, and water into complex organic substances which form the basis of the food chain. Some 10,000 of these fit somewhere into the scheme of human economic activity, including about 3,000 which have been grown for food. Only a few of these, however, are of major commercial importance—one hundred species or so—and only about 15 fill the bulk of the food requirements of our species. It is apparent that much remains to be discovered about many thousands of kinds of plants which could possibly be utilized.

Of course, not all agricultural scientists are engaged in research, but those who are have no lack of problems to solve. The questions in which they are interested run through the whole spectrum of biological disciplines. Sample topics for investigation might include: What do viruses do inside plants? What causes changes in fish population? What influences

learning and behavior in animals? What is the importance of bacteria in the stomachs of cows, deer, and other ruminants? What causes plants to flower and set seed? What happens when seeds become dormant, and how can dormancy be broken most readily so that seeds can germinate better? What nutritional factors in animal feed influence the quality of meat? How can depleted soils be best brought into production? What factors in air pollution affect the growth and quality of plants? The questions are endless.

Individuals trained in the sciences related to agriculture, horticulture, aquaculture and the like have many career opportunities in addition to research. An example of this: one of the nation's largest industries is the production of livestock for meat. There are managerial and production jobs in this industry which benefit from the knowledge of physiology, nutrition, genetics and range management which the bioscientist provides. Skills in engineering and business management will add to the value of the person seeking such jobs. Animal and plant products also undergo further processing before being offered to the consumer, and many thousands of trained people are employed by processing plants. Careers also exist in the communications aspect of agribusiness. Such careers require, in addition to technical competence, facilities in writing or public speaking. A thorough knowledge of English is a valuable asset for any career, but is especially necessary for the many jobs available in trade publications, livestock magazines, advertising agencies, and many other agencies servicing the industry. Individuals trained in animal science advise food processors, act as consultants to engineers who design machinery and equipment used in agriculture, assist breeders of horses, are involved in breeding and maintenance of laboratory animals, and help in the production and testing of chemical products for use in animal or human nutrition or medicine—to mention just a few applications of their skills.

The land grant colleges located in each state, as well as many other colleges, including some community colleges, offer training in animal science or other science applicable within the context of the above discussion. A typical course includes, in addition to the basic foundation in humanities and biological and physical sciences, applied subjects such as animal breeding, reproduction, nutrition, and various aspects of managing and handling animals. Communication skills and the economics of agribusiness may also be covered, including computer science. The learning is not all from books, for most such schools maintain flocks of poultry, herds of livestock, dairies, and even facilities for practicing the production and

packaging of foodstuffs and other products. Practice is also afforded in the all-important paper work. These specialty courses, of course, come after one has obtained the sort of background which any well educated person should have in basic science, mathematics, languages, and the humanities.

After obtaining such training, employment opportunities may be sought in many areas, including some of the industries mentioned above. Private research foundations employ many scientists with training in applied biology, as do industries engaged in service to agriculture, food processing, forestry products, and the like. The agricultural scientist may work in the classroom, laboratory, or experiment station. Agricultural colleges employ many teachers and research workers in biology. In order to fill such jobs, the student will generally need education beyond the baccalaureate degree, and many of the colleges offer graduate work leading to advanced degrees. Research agencies of the federal government and state agricultural experiment stations employ many thousands of agricultural scientists. Those in charge of the various projects typically have doctoral degrees, but there are many rewarding jobs which can be filled by those with baccalaureate or masters degrees. The person wishing eventually to obtain a doctorate can often fill the junior positions on the staff while working for a more advanced degree.

Sources of information on either educational or career opportunities include: the Committee on Educational Policy in Agriculture, National Academy of Sciences, National Research Council, 2101 Constitution Ave., Washington, D.C.; American Society of Animal Science, 309 West Clark St., Champaign, IL 61820; other sources are listed in the Appendix.

## FORESTRY

Like agricultural science, forestry is a highly practical subject. Indeed, in some lists, forestry is classified with the agricultural sciences. A *forester* must have training in both the scientific and practical aspects of the management of forest lands. Timber is an important biological resource, and it is the forester's job to see to it that it is used and yet perpetually maintained. The importance of forest products in our economy may be emphasized by citing a few figures: forest lands cover approximately one quarter of the total land area in the United States. Much of this is set aside as U.S. National Forest, in which tree harvests are regulated by the federal

government. There are National Forests in 39 states and Puerto Rico, and their total area amounts to about 15.6% of the area of the U.S. To get an idea of how large this is, if the National Forests were all in one continuous plot, it would cover all of New England, plus the states of New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, West Virginia, Ohio, and Kentucky— and still have enough left over to cover two thirds of the state of Indiana. In addition to the National Forests, many states have State Forest areas, and all the big timber companies have additional huge tracts of their own.

The United States and Canada together produce annually (as of 1980) more than half a million cubic meters of "roundwood"—available for lumber—or nearly 17% of the world total, while the amount of newsprint produced in the forests of these two countries was nearly twelve and a half million metric tons—a whopping 49% of the world total. And this was during a recession! The enormous job of supervising the culture, planting, growing, and harvesting of the trees needed to fill the demand gives employment to thousands of trained men and women. In this book, I'll not go into all the details of the careers available in this area, since the field is well covered in *Opportunities in Forestry Careers,* by Christopher Wille, as one of the series of Vocational Guidance Manuals, available in many school and college libraries. That book contains a list of forestry schools and suggestions for further reading.

The forester, like the plant pathologist, is concerned about plant diseases. Like the entomologist, he or she must be familiar with insects and their effects; like the ecologist, must understand the whole of the forest environment and be interested in conservation and the management of wildlife. The forester must have some expertise in all those fields. In addition, some foresters must learn how to manage outdoor recreation areas. An understanding of many of the technical aspects of wood products, pulp, and paper is also important.

Much of the forester's work is out-of-doors, but there is a great deal more to it than a perpetual outdoor hiking trip—much of the work is arduous and hazardous. As the forester gains experience, there may be more administrative and less field work to do.

High school graduates may attend any of a number of technical institutes which train people for technical jobs in forestry. For more responsible positions, the student should seek the more rigorous training available in colleges of forestry and obtain a bachelor's or master's degree. Those jobs involving scientific research, as well as the more advanced teaching

positions, are more likely to be filled by those with doctorate degrees. There are some 50 colleges in the United States offering courses in forestry, usually presenting four-year programs leading to the bachelor of science degree. At least two colleges of forestry concentrate on graduate students and do not offer undergraduate training.

To give some idea of the variety of jobs available to one trained in forestry, consider this partial list: Lumber Inspector, Forest Ecologist, Forest Products Technologist, Wood Products Salesman, Forestry Information Specialist, Campground Supervisor, Forest Pathologist, Urban Forester, Christmas Tree Grower, Wood Fuel Expert, Tree Geneticist, Forest Pest Controller, Forest Consultant, Tree Service Expert . . . . and so on.

Although the federal government is the largest employer of foresters. many states, cities, universities, and private corporations also offer employment opportunities. Private employers include lumber, pulp, paper, and other manufacturers of wood products; also railroads, water companies, recreation clubs, owners of large private estates, and others. Several departments and bureaus of the federal government employ foresters, but the majority of such employees are in the U.S. Forest Service.

## LABORATORY ASSISTANTS, TECHNICIANS, TECHNOLOGISTS

In any work which a scientist does, whether in a service laboratory, a research institute, a university or hospital, or in industry, he or she is part of a team. The leader of the team may be a highly trained scientist with a doctoral degree, but the work can progress only with the skilled and interested cooperation of technically trained coworkers. Technicians are the "doers," performing the practical operations, leaving theory to the scientist. Sometimes the technician is in training to become a scientist, but often the job of technician is regarded as a fully rewarding career in its own right.

The technician operates the laboratory equipment, often designs and constructs new equipment, makes drawings, builds models, estimates costs, makes repairs, keeps records, and assists in the interpretation of results. The positions offered are found by many to be pleasant and profitable, and there is often an opportunity to participate in research, if the technician is so inclined. So great is the variety of the work performed by techni-

cians and technologists that the National Health Council estimated that more than 200 such careers are available in the health field alone.

What makes a good technician? Let us attempt a partial list:

Some background in science and mathematics, but aimed more in a practical direction of problem solving than the more strictly theoretical training of the scientist.
Ability to work with the hands.
A practical bent.
Work habits that are systematic, precise, and patient.
Ability to work under pressure.
Capacity to work alone or with others.

The outlook for employment in this category is one of the brightest for any occupation. The Bureau of Labor Statistics of the U.S. Department of Labor has issued a projection of employment opportunities covering the period until 1990. Some of these predictions are as follows:

Technicians for agricultural and biological sciences . . . increase of 24.2%.
Clinical laboratory technicians . . . increase of 21.6%.
Health technologists and technicians . . . increase of 31.5%.
Foresters and conservationists . . . increase of 16.3%.
Therapy assistants . . . increase of 37.0%.
Health service workers—including dental assistants and health aides, but not such professionals as registered nurses, physicians, dentists etc. . . . a whopping increase of 60.0%.

All of the above percentages are estimates of the increase by the year 1990 compared with 1978. To give some idea of the actual numbers involved, employment for technicians in agricultural and biological sciences is expected to be more than 55,000, for clinical laboratory technicians about 265,000, for health technologists and technicians 671,000 — and for health service workers more than three million. These would all be rated as "white collar" jobs, and the Bureau pointed out that the proportion of jobs so classified has been steadily increasing since 1960, and will outnumber blue collar jobs during the 1980s and beyond.

Health service workers assist fully qualified health professionals such as physicians, dentists, and veterinarians in the handling of patients. For example, the *physician's assistant* may perform, under the close supervision of a physician, many tasks ordinarily performed by the physician, including obtaining case histories, scheduling laboratory tests, handling

emergencies, and other clinical procedures—indeed, the physician's assistant works so closely with the physician that he or she is known as a *paraprofessional,* and is officially recognized by the American Medical Association. The qualified health workers of which the physician's assistant is an example constitute such a large, growing, and important group of careers that they are dealt with in detail by a book *Opportunities in Paramedical Careers* as part of the VGM Career Horizon series.

Technicians and technologists require training beyond high school, but much of the skill required in these jobs can be obtained only on the job. There is a wide range of requirements for formal schooling. *Medical technologists* perform complicated bacteriological, chemical, microscopic, and other tasks; they usually have at least four years of college, with a baccalaureate degree. A similar training, though less complete, with two years of postsecondary schooling, may qualify one to be a *medical laboratory technician.* The technician displays a high degree of skill and performs a wide range of tests, but has less technical and theoretical knowledge than the technologist.

Sometimes laboratory technicians have the opportunity to study for advanced degrees and become professional bioscientists of the highest rank. Not all technicians entertain ambitions for such advancement, and many find satisfaction in a job well done in support of the laboratory's work. Individuals who fill these positions must have some training in theoretical and applied biology; they are recognized professionals or paraprofessionals, and they serve important functions.

Large numbers of workers are employed in medical laboratories supervised by pathologists. They receive special training which entitles them to be members of the Registry of Medical Technologists. Several levels of laboratory workers, depending upon the amount of training necessary, are recognized by the American Society of Clinical Pathologists (ASCP) and the American Society of Medical Technologists. The *certified laboratory assistant* (CLA) receives accreditation after one year's study beyond high school in a laboratory assistant school accredited by the American Medical Association. The *histologic technician* is a high school graduate who has spent one year after graduation in a hospital training program or junior college. The job consists of preparing microscope slides for study by the pathologist. The CLA and the histologic technician may obtain employment in a clinic, physician's office, public health agency, or a variety of industrial, pharmaceutical, and military laboratories. The *cytotechnologist* works in a restricted specialty involving microscopic study of cells to assist

in the diagnosis of cancer. This specialty requires two years of college, an additional year in an accredited school, and practical experience. Scholarships are available for students in cytotechnology.

Becoming a *medical laboratory technician* requires completion of two years of college (an associate degree program) and supervised clinical experience in an approved laboratory. The *medical technologist* performs somewhat more advanced duties, and the training requires four years of study beyond high school: three years in college with courses in biology, chemistry, and mathematics, and a fourth year in an accredited technology program connected with a hospital, studying under the direction of a pathologist. Many universities give a combined course, so that the whole four years may be taken in one location: a baccalaureate degree is awarded at the end of the course. Medical technologists are in great demand, and their work is varied and interesting, involving the performance of chemical, microscopic, bacteriological, and other tests. The practitioners of this specialty work in laboratories connected with physician's offices, hospitals and clinics, independent service laboratories, government agencies, and industry. They often advance to positions as supervisors, teachers, or research assistants.

The American Association of Pathologists maintains an office at 9650 Rockville Pike, Bethesda, Maryland 20814, and full information about these recognized categories of laboratory workers can be obtained from them. Many of the schools where training for these jobs can be obtained are in state supported universities, but there are also many private technical schools which specialize in this field. An up-to-date list of the accredited private schools is contained in the *Handbook of Trade and Technical Careers and Training* which may be obtained free of charge from the *National Association of Trade and Technical Schools,* 2021 K St., N.W., Washington, D.C. 20006. Most of the members of this association offer training totally unrelated to bioscience, but many do include complete courses in laboratory technology. A student needing financial assistance to attend one of these—or for that matter, other schools—can obtain information from the Bureau of Financial Assistance, P.O. Box 84, Washington, D.C. 20044.

There are many categories of workers in medical laboratories in addition to the above. Indeed, it has been said that of all the fields hiring technicians, medicine offers the greatest diversity of careers. To mention just a few more: an *electrocardiographic technician* learns to record electrograms for the physician after a training period which is usually a few months to a

year. A somewhat longer period of training—up to two years—is undertaken by the *electroencephalographic technician,* who learns to record the electrical activity of the brain—the EEG. Instruction in anatomy, neurology, medicine, psychiatry, and electronic instrumentation is supplemented by laboratory experience. *Radiologic technologists* not only take and develop X-ray pictures, but help treat patients by administering radiation therapy; they work closely with radiologists, and the course of training takes from two to four years. The *microbiology technologist* must have a bachelor's degree, preferably with a microbiology major, followed by a year's experience beyond college. The *blood bank technologist* also requires a baccalaureate degree, preferably with a major in biology, followed by a year in a school approved by the American Association of Blood Banks.

There are many areas of biological sciences that employ technicians besides those related to medicine. Practically all scientists need technical assistance. In some instances, a high school graduate who has a good record in bioscience and other sciences and a strong desire to learn on the job may obtain one of these positions directly, but more often the employer would give preference to one with further education. There are many opportunities for technicians with a baccalaureate degree with a biology major, even without any specific training as technician; it depends upon the flexibility of the employer. The *Occupational Outlook Handbook* published by the Department of Labor is one source of information on technical institutes which offer training to qualify students for a job immediately after graduation. These curricula, some of them in junior and community colleges, are similar to the first two years of a four-year college, and the graduate may either qualify for a technical job then, or transfer for further education.

There are specific courses for training *food science technicians, marine science technicians, natural resources conservationists, animal husbandry technicians, plant science technicians, soil science technicians,* and so on. As an example of the kind of work one of these technical assistants might do, a plant science technician, after one to two years training, might assist an agronomist (one skilled in the scientific management of crops) in experiments on basic nutrition of plants, on breeding and selection of plants, or on a study of plant diseases or relationships with insects, or in discovering new economic uses of plants. Chemical analyses of plants, collection and preservation of specimens might be other objects of attention. Other biological scientists—ecologists, zoologists, physiologists, pharmacologists,

biochemists, biophysicists, and many others—also benefit from the services of technicians.

Animal technicians assist veterinarians and research workers in biology. They care for and feed animals, keep records, maintain equipment, prepare animal patients for surgery, collect specimens for laboratory analysis, dress wounds, and perform many kinds of laboratory procedures. In recent years, there has been increasing recognition of the need to upgrade the technicial skills of the workers who handle animals in biological research laboratories, veterinary practice and research, or any area where science and animal care are combined. Especially active in promoting improvements in animal care and handling are the American Veterinary Medical Association (AVMA) and the American Association for Laboratory Animal Science (AALAS). According to a publication of the AALAS, a laboratory animal technician is a person in a position requiring education below the doctoral level.

The AALAS seeks to improve the abilities and status of animal laboratory workers by developing standards of training and by recognizing individual accomplishment through a three-level program of certification. The animal caretaker, with the title of *Assistant Laboratory Animal Technician,* provides the day-to-day maintenance of the animals and their quarters under supervision. After completing a course (which may be on the job) and then one year of experience, the caretaker is eligible to take an AALAS-sponsored examination for certification. The next grade, *Laboratory Animal Technician,* requires three years of experience, two of which may be spent in a laboratory animal technology school after graduation from high school. The *Laboratory Animal Technologist* may have a baccalaureate or master's degree in animal science or related technical program. Work experience of six years may be allowed in lieu of a degree; in any event, written examinations must be passed.

## WRITING IN THE BIOLOGICAL SCIENCES

No matter what field of bioscience you are in, or what the level of your career, you'll find times when it is to your advantage to be able to write well. The technician must keep clear and accurate notes of his or her observations, and may be called upon to submit reports to the scientist in charge of the laboratory or the field trip. The professional scientist will discover that as one's career advances, the demands for writing become

more and more insistent. Some may wish to communicate with the public as well as with fellow scientists, and may wish to make a career of writing. Articles on science are popular with editors of newspapers and magazines, but few individual papers employ science writers; most of them buy articles on science from syndicates.

In order to advance scientific knowledge, it is essential that new discoveries be reported in such clear language that the discoverer's colleagues can understand it—and if necessary, repeat the observations. Indeed, a scientist's reputation is largely based on such communications. For this reason, the biologist who has writing ability has an advantage over one who does not. Most scientists—as well as most other people—find writing to be hard work, and no one ever becomes able to communicate *all* of one's thoughts to another person. Nevertheless, there are some who become so skillful at it that it becomes a pleasure (even though it remains hard work), and some devote full time to it.

Practically all scientists do some writing as part of their career work. Universities require candidates for doctoral degrees to write dissertations; these are often very long and elaborate descriptions of the work done, the reasons for undertaking the job, the historical background, and the interpretation of the results. This is, in a way, practice for what the scientist will do in the future—the research worker, especially in a university, must write papers reporting the results of the research. Unless this is done, the research has not really contributed anything to knowledge, nor is the worker likely to receive rapid promotion in the job, no matter how skillful the worker is in other respects. The worker outdoors in the field often makes observations which need to be communicated to colleagues. The educator may write reports on new teaching techniques or on especially informative experiences in the classroom. If you intend to be a professional scientist, you should start learning to write well as soon as possible.

The scientist who has written a number of such reports will sometimes undertake a more ambitious writing project in the form of an advanced treatise or "monograph." A monograph is a highly specialized book attempting to cover what is known about a specific—and usually rather narrowly circumscribed—aspect of a subject. A monograph may have a single author, or different authors may write the various chapters in the book, with one of them serving as editor of the entire monograph. If a scientist has acquired a reputation for writing research papers, it is likely that at some point in her or his career the person will be invited to write some sort of "review" or other monograph.

Biologists also write laboratory handbooks and textbooks intended for class use. Most publishers send each of their new scientific books to the editors of *American Scientist* and other professional journals in the hope that they will receive favorable reviews. The number of such new books received for review each year exceeds a thousand, and the editors of *American Scientist* engage more than 350 scientists to read and review the books received.

In a somewhat different category is science writing done for the general reader. This may take the form of articles for newspapers or magazines, columns reporting the latest developments, interpreting science news for the public, or answering reader's questions. Professional science writers particularly skilled in summarizing current trends in scientific discovery and thought may find employment on the staff of a magazine devoted to popular accounts of science—such periodicals as *Science News, Popular Science, Science Digest,* for example. A different kind of science writing is to be found in *Scientific American,* which publishes semi-technical articles, often by scientists in one specialty explaining their work to those in unrelated fields. Popular nontechnical books addressed to the general reader also are much in demand.

In the past, scientists in general and biologists in particular have been critical of much of the reporting of science news in newspapers and magazines, feeling that many of the reporters lacked scientific insight and thought in terms of "human interest" of their stories. This handicap, coupled with the lack of cooperation from biologists who often held themselves to be "above" talking to representatives of the press, sometimes led to misleading stories. Mistakes still occur in some science reporting, but in general there has been a trend for the press to hire science reporters who have had training in biology—some of them even hold advanced degrees. Such people are truly professional science writers, and they have an organization whose aim is to maintain high standards. There has also been a change in the attitude of many biologists toward the press; many meetings of biologists now feature newsrooms where scientists and reporters can meet together, and some societies prepare news releases describing in nontechnical language some of the reports presented by the scientists to their assembled colleagues.

Generally speaking, the biologist who writes reports of work for the information of colleagues for publication in scientific journals receives no monetary compensation for these efforts. Technical journals appeal only to a limited readership and cannot afford to pay their authors; indeed, often

The journals make an important contribution, often being the first to publish reports on work like that of Dr. Randolph Henke, above, whose team of biotechnology researchers is studying improvement of grains through mutagenesis. Photo: University of Tennessee, Knoxville, and Agrigenetics Research Corp., Denver.

the author or the scientist's institution is required to pay "page charges" to the journal. The author of an advanced technical manual or monograph fares somewhat better—but not much. These highly specialized books cost just as much to produce as do basic textbooks, and sometimes more. But it is easy to see that a monograph with a sale of 4,000 copies will cost much more per copy than a textbook which sells 100,000 copies. Not only does the monograph have a limited appeal, but its high price further reduces sales. Hence, even if the author has a favorable royalty agreement with the publisher, the scientist would not consider writing a technical book about her or his specialty as a means of income. The rewards must be the more intangible ones of prestige and the personal satisfactions that come from a job well done and from seeing one's work in print.

Writing books for the general public, on the other hand, or writing textbooks for class use, can be profitable either as a sideline or in some instances as a full-time career. Beginning authors sometimes have illusions about their writing abilities, the importance of their manuscripts, and the financial returns to be expected. Skill in writing sufficient to turn out acceptable manuscripts requires years of practice beyond what can be learned

in a freshman composition course. Although publishers will read unsolicited manuscripts, the most favorable reception will likely be given to manuscripts which the editor is expecting. The groundwork may be laid by previous correspondence between editor and author, but authors who are interested in writing as a full-time career usually employ literary agents.

Even the most popular books on biological subjects seldom make the bestseller lists, but there are a few exceptions; books by Konrad Lorenz, the late Rachel Carson, and a few others have been very successful. The most successful authors of textbooks or books for the general public often have several books on the market at the same time. In that way, royalties will be coming in from the older books while the newer ones are establishing their places in the market. A few individuals have built rewarding careers in this way. One who has done so wrote an article "Writing Careers in Biology". Although this appeared some years ago—in the April, 1968 issue of *The American Biology Teacher*—it is still interesting reading for anyone wishing to learn about biological writing from a successful professional. More general comments about writing will be found in "Writing in the Life Sciences" by S. L. Weinberg, in *The American Biology Teacher,* March, 1978. You may also wish to consult some of the "Opportunities" books of the Vocational Guidance Manuals series: *Writing Careers,* by E. Foote-Smith, *Technical Communications* by J. Gould and W. Losano, *Magazine Publishing* by J. Tebbel, or *Women in Communications,* by A. Fins.

An ornithologist banding a Mallard duck for survey at Bosque del Apache National Wildlife Refuge, San Antonio, New Mexico. Photo: U.S. Department of the Interior Fish and Wildlife Service, photographer L.A. Mehrhoff.

CHAPTER 7

# THE EMPLOYMENT OF BIOLOGISTS

In previous chapters we have mentioned some of the places where biologists work—the organizations, institutions, and industries which employ them. We can now summarize some of this information and add some further details.

## EDUCATIONAL INSTITUTIONS

Educational institutions which employ biologists include secondary schools, both public and private, colleges, universities, professional schools, and many kinds of technical schools. Teaching can be one of the most rewarding professions you can find. One biology teacher in a secondary school recently wrote " . . . the teaching of biology can be a dream come true, with all its attendant frustrations and rewards. I wouldn't trade it for anything".

New developments have come so fast that some have predicted an increasing demand for biologists for the remainder of the twentieth century. A possible exception to this may be the need for teachers. Enrollment in secondary schools markedly increased during the 1960s and early seventies, reaching a peak in 1976. At that time, the number of high school (grades 9—12) students was nearly 62 per cent higher than in 1960. The trend has been downward since then, and it is projected by the National Center of Educational Statistics that by 1990 enrollment will have dropped by 21 per cent from the peak. A smaller drop is expected in enrollment in institutions of higher learning, with a small drop in instructional staff.

Statistics such as these may be a bit misleading, and the outlook for

teachers trained in biology is considerably brighter than they indicate. For one thing, many new teachers are required to replace those retiring or leaving the profession. Many states are attempting to increase the science requirements for graduation, and are having difficulty recruiting enough qualified teachers to implement their plans. According to the National Science Teachers Association, no less than 42 states had a shortage of science teachers in 1982.

So we have a paradoxical situation of declining total enrollment and some shrinkage in numbers of teachers both in high school and college, but possibly even an increase in demand for qualified teachers of science, especially biology.

The thirty thousand or so secondary schools in the United States constitute the largest market for teaching skills. The high school biology teacher is not charged with the responsibility of training professional biologists, but a good teacher will inspire some of the students to be interested in a biological career. The main task of the teacher is to educate responsible citizens, and in our increasingly technological society a well rounded person must have some knowledge of biological and other sciences.

The teacher in high school or junior college will usually be required to obtain a good background of biology courses in addition to studying teaching methods and science education. In general, teachers in four-year colleges and universities are not required to take courses in "teaching methods," although no doubt some of them could benefit from such courses.

The biology teacher in secondary school is a professional teacher who has specialized in biology. Although the demands on the teacher's time are different from those of the research worker, he or she is equally challenged to keep up to date. A part of the job of teaching students to learn is to understand and apply the art of learning.

Not only is biology changing rapidly, but the methods of presenting biology to the students have undergone profound changes since the reports of the BSCS (Biological Sciences Curriculum Study). The teacher must keep up with developments, but is aided in doing so by such organizations as the American Association for the Advancement of Science, the American Institute of Biological Sciences, the National Science Teachers Association, and the National Association of Biology Teachers. These organizations publish periodicals and hold meetings which inform the teacher of new discoveries, as well as new ideas in teaching. Summer

courses are available at many colleges and universities, and at biological stations, usually operated by universities. Teachers in secondary school face a special challenge in the great diversity among their students, some of whom may never take another science course, while others will exhibit unrestrained enthusiasm for the subject and will go on to a full time career.

Although most biology teachers are specially trained, some have entered the profession from other disciplines simply because they find biology more interesting than their former employment. These recruits sometimes are teachers from other subjects and sometimes are biologists who have worked in industrial or government laboratories or elsewhere and have decided that they prefer teaching. The college training for biology teachers in secondary schools includes a broad study of many biological subjects, including both laboratory and field work, and both plant and animal material. Courses in chemistry and physics are also essential; indeed, in some small schools a teacher may be called upon to teach more than one science. The college student intending to teach biology should gain as much experience as possible in practice teaching. He or she will also find it advantageous to find summer employment in a biologically oriented job, such as work in medical or research laboratories, conservation projects, forests, etc.

Most biology teachers in elementary or secondary school have entered the profession immediately after completing college, but more and more find it desirable to continue study until a master's degree is obtained. The standards for high school teachers are being elevated, and in some of the better school systems the master's degree is the "ticket" for entrance. Training programs covering a five-year period and culminating in the master's degree are available in some training centers for teachers. The Ph.D. or Sc.D. degree is primarily a research degree. Although generally needed for careers in teaching in a university, it is not required for secondary school. This is just as well, for the emphasis on research which is necessary during the study for the doctorate is of limited value for the kind of work the high school teacher will be doing.

The high school teacher is a highly respected member of the community, and in recent years his prestige has grown. There are many rewards, both tangible and intangible, for the devoted teacher, and working conditions and pay scales are improving constantly. There is never an oversupply of competent and devoted teachers.

As employers, high schools generally use different criteria in hiring than

do other employers of biologists. The high school teacher will usually be required to have studied courses in teaching methods and in science education in addition to biology and related sciences. The beginning teacher will be expected to have a bachelor's degree, or preferably a master's degree. In addition, such teachers may be expected to continue their education by summer study or other means.

Unlike the secondary teacher, the university teacher of biology is likely to consider herself or himself as primarily a professional biologist and only secondarily a teacher. College teachers usually earn a doctoral degree before becoming full-time faculty members, and doctoral training is strongly slanted toward stimulating interest in research. The advanced degree, Ph.D. or Sc.D., is awarded as a result of concentrated study of a highly specialized field, and colleges will consider for hiring only those individuals whose specialized study is closely related to the subject which the new instructor is expected to teach. If you obtain a Ph.D. in a Department of Education, for example, you cannot expect to obtain a job teaching in a university biology department.

The preparation for a teaching career in a college is the same as that for a full-time research worker. Most colleges and universities, especially the larger ones and those with the greatest prestige, expect faculty members to combine teaching and research careers. In that way, the college teacher not only passes along to the next generation the knowledge accumulated in the past, but also keeps in the forefront of new developments. The young man or woman just beginning a teaching career in college may be given the title of instructor, but with some experience may look forward to promotions—to assistant professor, then associate professor, and finally professor. With each increase in rank there is an increase in salary, greater opportunities to teach more advanced courses and guide young graduate students who will be the next generation of college teachers, and greater responsibilities in serving on committees which help guide the policies of the institution.

Colleges offer many attractions for those considering a teaching career. They are frequently located in pleasant towns or in cities with many cultural advantages. The faculty members form a community of people with a similar level of education, and with many interests, hopes, and aspirations in common. To an extraordinary degree, the teacher is her or his own boss, and one is free to plan one's own time and to do the work in one's own way.

Many universities have more than one department which employ biological scientists while smaller colleges may have but a single depart-

ment of biology. Larger ones may have separate departments of botany and zoology. Many other arrangements are possible, and there may be several departments representing the various biological disciplines. Colleges of agriculture, with their emphasis on applied biology, utilize an especially large variety of biological skills. Specialists in several biosciences are to be found in colleges of medicine, dentistry, pharmacy, and veterinary medicine; these schools are usually integral parts of universities, but some are independent.

It might be helpful for you to visit one or more of the colleges or professional schools near you, seek out the biologists working in them, and talk with them. The more different kinds of biologists you talk with, the better your own judgment may be about selecting a similar kind of career. You will find most of them glad for a chance to talk about their work and especially happy to welcome a prospective recruit to their profession. But don't expect them to make up your mind for you; you must do that yourself.

If you are considering biology teaching as a career, you should not overlook the possibilities offered by junior or community colleges. Although the courses of instruction are not as advanced as in four-year colleges, most of them offer courses of sufficient diversity to interest most biologists. In some instances, their programs of general biology are at least as good as those of the lower divisions of four-year colleges. Unlike the four-year college, the junior college often requires applicants for teaching jobs to obtain teaching certificates, but requirements for certification of junior college teachers differ from state to state. For specific information, you may contact the department of education of your state university.

The teaching load in junior colleges—the number of hours per week actually spent in the classroom—is usually somewhat less than that required in high schools, but greater than that demanded in senior colleges. The senior college teacher is expected to spend a significant portion of his time in scholarly pursuits such as writing or research. Often, salary scales are lower in junior colleges than in either high schools or four-year colleges, but in recent years they have improved. The teacher who wishes to spend part of the time in research will find that the junior college offers less opportunity than does the senior college. There are, then, some frustrations accompanying junior college teaching, but the dedicated and enthusiastic teacher finds that they add to the interest and challenge of the job. Some teachers feel that the junior college offers the most exciting and rewarding field in the educational world.

## GOVERNMENTAL AGENCIES

The largest employer of biologists or of those whose work is closely related to biology is the federal government. Biologists may be found in most of the departments. Let us look, for example, at the Department of Interior which is charged with the duty of conservation of natural resources. A list of the agencies within that department which employ bioscientists and biologically oriented people includes the Bureau of Commercial Fisheries, Bureau of Sport Fisheries and Wildlife, Bureau of Land Management, National Park Service, Bureau of Outdoor Recreation, Geological Survey, Federal Water Pollution Control Administration, Bureau of Reclamation, Office of Saline Water, Office of Water Resources Research, Bureau of Indian Affairs, Office of Territories, and Office of the Science Advisor. The National Park System, for example, has nearly 100 natural areas where there are employees with a background in the life sciences. The majority of the national park superintendants have training in bioscience together with many years of experience within the park system. Life science majors begin as park rangers; the competition for these positions is keen. Rangers have to deal not only with environmental problems but with people problems as well.

Even the large number of positions for bioscientists in the Department of Interior is exceeded by the Department of Agriculture, which is the largest employer of biologists.

The multiplicity of jobs within the federal government is indicated by the following list—a very incomplete list—issued by various agencies and classified in biological sciences:

Agricultural Bacteriology
Agricultural Technology
Agronomy
Animal Physiology
Bacteriology
Biology
Biological Aide
Cereal Technology
Cotton Technology
Dairy Husbandry
Ecology
Editor
Entomology
Fish Culture
Fishery Research Biology
Forestry
Forestry Research
Gardening
Genetics
Herbarium Aide
Horticulture
Hydrology
Illustrator
Investigator
Librarian
Medical Biology Technology

Microbiology
Microanalysis
Mycology
Nematology
Nutritionist
Parasitology
Park Naturalist
Park Ranger
Pharmacology
Plant Pathology
Plant Physiology
Plant Taxonomy
Poultry Husbandry
Predator and Rodent Control
Range Management and Conservation
Seed Technology
Soil Science
Systematic Zoology
Tree Culture
Wildlife Management
Wildlife Research Biology
Zoology

The above list of 48 jobs in various government agencies is a purely arbitrary one of actual titles of positions selected by the author and arranged alphabetically. You can judge its incompleteness by the fact that the Department of Agriculture alone has a list more than twice as long. Some of the categories, though, seem to be less directly related to biology than are those above.

A career in government service has many attractive features for biologists. Employment conditions are good, and the increasing emphasis on life sciences bodes well for the future. Fully qualified applicants are often hired on the basis of education and experience, without the necessity of taking a civil service examination. The levels of jobs range all the way from the so-called "blue collar" jobs for those not yet fully trained to the "supergrades" for distinguished scientists.

For those who start to work before completing their training, the government offers educational assistance programs. Arrangements are made for the employee to receive full pay while attending classes at a nearby university part-time, or even full-time up to one year. After completing this training, of course, the employee is in line for a job with a higher rating.

Government positions offer an unusual degree of security, which is protected by the civil service system. There is little danger that the job will be lost as long as the employee wants to keep it. The salary scale is close to that in private industry, and somewhat better than in the educational world. The government scientist has good laboratories and equipment, and much freedom in doing the job her or his own way. The scientist in government can publish the results of the work in scientific journals and hence achieve a reputation in the world of science. Part or all of the expenses for attendance at scientific meetings will also be reimbursed. Other

fringe benefits such as group life insurance, health insurance, and retirement pay are comparable to those available elsewhere. A scientist who works in the laboratory or in the field may wish to continue to do so until retirement or may have an opportunity to become an executive and help administer the programs of the department. Either way, there are opportunities for advancement.

One can obtain information about government jobs by contacting the Federal Job Information Center; there are more than 100 such centers across the country which provide local job information. They are listed under "U.S. Government" in the telephone directories of metropolitan centers, or you can obtain the local number by dialing 800-555-1212 (the telephone information number). One office that is not very well known by the general public is the Federal Information Center, General Service Administration, Washington, D.C. 20405, which will answer any question relating to services of the federal government; the FIC has only one function: to help find the government agency and the correct person to answer your question.

Although the government service is centered around Washington, D.C., employees of such agencies as the Department of Agriculture, the Department of the Interior, the Public Health Service, and others are to be found in all the states, and in some instances their duties take them overseas.

We should not leave the area of federal service without mentioning the Food and Drug Administration. This important agency, a part of the Department of Health, Education, and Welfare, employs a large number of biological scientists and has a continuing need for biologists, chemists, and other scientists of the highest caliber. The FDA is charged with the duty of ensuring that foods, drugs, and cosmetics sold in the United States are safe, properly manufactured, honestly advertised, and effective for the purpose for which they are sold (some foods, especially meats, are inspected by the Department of Agriculture).

Each of the states, and some cities, employ biological scientists in roles similar to many of the federal jobs. Biologically oriented agencies of state and local governments include fish and game commissions, parks, aquariums, arboretums, museums, and the like. On the average, these positions pay slightly less than comparable jobs in the federal service, and such fringe benefits as vacation time, sick leave, insurance, and retirement pay are not quite as generous at those enjoyed by federal workers.

In summary, whatever your interests in biology might be—whether you would like to work outdoors in field or forest, streams or seas, or indoors

in laboratory or at a desk, in routine work or in research, in doing your own work or in supervising and administering the work of others—a place can be found in government service. If, however, you want to experience the thrill of bringing young people into their first contact with the exciting world of biology, and watch them mature into scientists in their own right, you will do better in teaching.

## INDUSTRY

Most of the research and development in our country is performed in industry, but there are a great many biologically oriented jobs outside of the research function. For example, many industries depend upon microorganisms for production of their products. Some of these, such as cheeses, alcoholic beverages, and baked goods have a long history, with records going back to about 6000 B.C. Others are of recent origin and owe their existence to new developments in biological science; prominent among these is the manufacture of pharmaceutical products by enzymatic action of microorganisms in large vats, followed by extraction and chemical isolation of the desired products. Some industrial biologists are using microorganisms for the production of methane and alcohol from waste products as alternate energy sources. Even the yields of minerals in low grade ore deposits are being improved by microorganisms in some processes. Purification and recycling of water also gives employment to some biologists in industry.

Individuals with biological qualifications are employed by an astonishing variety of business and industrial concerns. An indication of the importance of this source of employment for biologists can be obtained by listing some of the industries involved. The chemical industry offers many opportunities. Prominent in this category are those firms producing agricultural chemicals, including substances used for controlling pests or stimulating crop production, as well as dietary supplements for nutrition of animals or humans.

Among those offering positions with biological orientation are processors of foods and beverages, the manufacturers of cosmetics, the agricultural industries needing the skills of animal or plant husbandmen, the breeders of fur-bearing animals, fisheries, forest products companies, and even such concerns as the manufacturers of textiles, leather goods, and petroleum products, as well as public utility companies and the aerospace

industry. Still others are the publishers of biological books, manufacturers of laboratory equipment, general laboratory supply houses, and those companies which make a business of collecting, culturing, and processing biological material for the use of educational institutions and research laboratories. There is scarcely any biological discipline mentioned in this book that is not represented in one or more of the industries just listed.

One growing industry is made up of companies which perform scientific services under contract for others. Some of them do biological testing exclusively, while others include biology but have other departments as well. The customers of the biological testing companies include the U.S. government, drug companies, cosmetic manufacturers, and a variety of other individuals and corporations. Many of the customers have testing laboratories of their own but sometimes need the additional help of the service companies. Although much of the work is routine, the testing laboratories also do a considerable amount of research and some of their bioscientists are highly regarded by their colleagues in other organizations. The biological disciplines represented in this industry include nutrition, biochemistry, physiology, pharmacology, microbiology, cytology, histology, toxicology, and pathology.

Manufacturers of pharmaceutical products probably employ more biologists than any other industry. The range of jobs in the drug industry includes biological manufacturing and packaging, quality control, biological testing of products, writing of brochures, reports, and correspondence, training of workers; but especially noteworthy is the magnitude of the research efforts. More than 20,000 people are employed in the research laboratories of this one industry, and an extraordinarily high percentage of them have a background in biological science. The demand for biologists and other scientists in the pharmaceutical industry continued to grow even during years of recession. The industry spends the exceptionally high figure of more than 11 per cent of its sales revenue on research and development. The growth of the opportunities for scientifically trained personnel can be illustrated by the growth record of one company—the company with the largest research budget—which expended about $61 million for research in 1969, $125 million in 1975, and about $370 million in 1983—a six-fold increase in 14 years. Payment of salaries for an increasing number of people accounted for a very large part of this growth.

For our present discussion, the significance of such figures is that career opportunities are offered for those with the training to take advantage of

them. The scientist in the pharmaceutical industry is, by and large, given whatever is needed in the way of materials, equipment, and assistants to do the job. The work is expensive, partly because of some 175,000 new chemicals tested in a year, not more than 8 out of each 1,000 show enough promise to warrant testing in humans, and in some instances all but one in 15,000 are rejected before they reach the market.

In spite of these difficulties, the industry points with pride to the fact that over the past 35 years 90 percent of all the world's drugs—nearly 600 new chemical entities—have been discovered and developed by the scientists in its employ. Most of these scientists are either chemists or biologists, and their discoveries have revolutionized the treatment and prevention of disease.

The research biologist in the drug industry is able, to a degree unmatched anywhere else, to work in collaboration with scientists in disciplines other than his or her own, whether it be in physical sciences or other biosciences. Cooperation between biologists and chemists is a daily occurrence, and the biologist often consults with physicists, mathematicians, psychologists, and pharmacists, to mention a few. Bioscience disciplines represented in the industry include physiology, biochemistry, toxicology, pharmacology, pathology, animal husbandry, microbiology, immunology, systematic botany, entomology, and nutrition.

Papers and monographs written by industrial scientists are published in the leading scientific journals and books, and research workers in industry often hold high positions in scientific societies. These are developments of the past few years, for many of us can remember when scientists who worked for industry—especially biological scientists—were held in low esteem by their academic colleagues. A major reason for improvement in this attitude is the enlightened attitude of many companies who have come to realize that scientists require a different kind of environment than do people with commercial interests. Now, there is a fair amount of interchange between the academic world and industry; some university professors forsake academia for jobs in industry, while many scientists leave industry for teaching positions. In addition, many industrial scientists hold part-time teaching appointments in nearby universities.

The professional levels of biologists in the drug industry range all the way from beginners with baccalaureate degrees working as technicians to scientists of international renown. The beginner is encouraged to continue his education while receiving full pay from the company; most companies pay the tuition charges for part-time study at a nearby college or universi-

ty. Many of the pharmaceutical laboratories are built in pleasant rural or suburban locations, in keeping with efforts to make working conditions as pleasant as possible. Salaries are slightly higher than in colleges, and the fringe benefits of vacations, sick leave, insurance, pensions, etc. are among the most liberal of any industry.

Jobs with biological orientation but outside research departments are becoming more common in industry. Some companies prefer professionally trained representatives to present their products to customers. These are not salesmen in the old sense but individuals who provide a liaison between company and customer. Others employ professional people in training programs for sales personnel and technical representatives. If you can combine technical competence with a flair for writing you will find that there is a brisk demand for staff writers and editors. In summary, despite obvious differences between the academic life and industry, you will find the same types of people in both, and there are as many varieties of opportunities in one as in the other.

## SELF-EMPLOYMENT OPPORTUNITIES

One other commercial outlet for biological talent remains to be discussed: namely, the biologist who goes into business for himself. We have already discussed the biological testing industry; several of the laboratories in that category were started by biological scientists. Starting such a project requires an amount of capital that is not readily available to everyone. Easier to start are laboratories which perform testing services for physicians and hospitals. Although most hospitals have their own laboratories for biological and biochemical examinations, there are also large numbers of independent laboratories performing such services. To be successful in such a venture, you should have a thorough background in the technical aspects of biochemistry, hematology, and in the preparation of microscope slides. The more successful of such ventures have proven to be highly rewarding financially.

Self-employment opportunities are also available for botanists. Some of them become greenhouse operators who may engage in a particularly lucrative specialty, such as the growing of orchids. Botanical systematists become consultants to industry. Plant pathologists are also in demand as consultants, and some of them go into private practice. The number of self-employed botanists is small but some find that their business pays well.

The collection, preservation, and sale of biological specimens is another source of self-employment. Vast numbers of living and preserved frogs, turtles, earthworms, sharks, sea urchins, anemones, seaweeds, seed-bearing plants, and other plant and animal organisms are used for teaching and research in schools, colleges, and research laboratories. The demand for them in the past has been met almost entirely by collecting wild specimens, but with the growing threat to the survival of many species, "farming" must be considered as a source for the future. The demand fluctuates with the number of students of biology and the generosity of school budgets for materials.

## INDEPENDENT RESEARCH LABORATORIES

Research laboratories which are neither directly connected with industry nor a part of a specific department of a university receive their support in a variety of ways. Some of them depend largely upon the income from endowment funds which have been donated by an individual or group wishing to use their wealth in a constructive way. Others depend more upon annual contributions. Most of them accept grants of money from government funds or from interested industries. Whatever their sources of income, large numbers of bioscientists ranging in rank and status all the way from laboratory assistants to Nobel Prize winning scientists find a stable and congenial atmosphere for their research. The same wide range of biological and biomedical disciplines is to be found in the independent research laboratories as in universities or industrial installations. The qualifications for appointment are the same, and salaries and fringe benefits do not differ greatly. In some of them, it is also possible to participate in the education and training of young scientists and to hold faculty rank in a nearby university.

There are independent laboratories in every section of the country. The following few examples will illustrate the wide variety of interests among these institutions, and you may note that some of them are so well known as to be almost household words:

*Jackson Laboratory,* Bar Harbor, Maine 04609, is famed for genetic studies, especially on unique strains of mice.

*Marine Biological Laboratory,* Woods Hole, Massachusetts 02543, is a favorite spot for many biologists in the summer time, but is active the year round in collecting and culturing marine organisms and in

biological research.

*Research Triangle Park,* North Carolina 27709, was originally a joint venture of three universities, but now includes several associated laboratories supported by industry and others, forming a collection of laboratories including biological and other sciences.

*Roswell Park Memorial Institute,* Buffalo, New York 14263, has achieved an enviable reputation for cancer research.

*Wistar Institute of Anatomy and Biology,* Philadelphia, Pennsylvania 19104, is not only a research and teaching center, but has been known as a source of laboratory animals, such as the famed "Wistar Rat".

*The Worcester Foundation for Experimental Biology,* Shrewsbury, Massachusetts 01545, is known for work on endocrine physiology, especially for its origin of "The Pill" but carries on other biological work, too.

*Mayo Clinic and Foundation,* Rochester, Minnesota 55905, is more than just a hospital, but is also a laboratory for a wide variety of research and training in the biomedical sciences.

*The Salk Institute of Biological Studies,* San Diego, California 92138, is named in honor of its Director, Dr. Jonas Salk of polio vaccine fame.

## BOTANICAL GARDENS AND ARBORETUMS

If you have never visited a botanical garden or arboretum, it may surprise you to learn that there are many kinds of careers available in these interesting places and a considerable demand for men and women to fill staff positions. Botanical gardens are more than just beautiful displays of trees and flowers. They typically have many varieties of plants growing in the open and more in greenhouses and conservatories. The care of these plants is much more demanding than that of the usual commercial greenhouse or nursery. The latter will have no more than a few dozen kinds of plants, but a large botanical garden may have several thousand different species of plants, each with its own particular requirements for growth and propagation. In addition, botanical gardens and arboretums maintain collections of dried specimens. These collections can be very

large—The New York Botanical Garden has more than three million specimens.

These gardens are not merely repositories of stationary specimens. They are also educational institutions, and many of them also conduct extensive research. Some of the subjects of research are ecology, plant anatomy, systematic botany, economic botany, plant physiology, phytopathology, biochemistry, and a host of other topics. Sometimes research botanists and curators hold professorships in nearby universities. Graduate students in some departments of botany can complete all their research for advanced degrees at a botanical garden or arboretum.

Botanical gardens offer educational programs to school children and to the general public. These programs consist not only of labeled collections of plants, but also of exhibits, classes, lectures, publications, and the furnishing of background material in botany for schools of all levels. This is a two-way street, with students being given an opportunity to visit the botanical garden, and also the staff enjoying contact with teachers and students in the classroom. Staff members especially skilled in these activities have not always been easy to find, and directors of the gardens are on the outlook for promising candidates.

The kinds of jobs available in botanical gardens and arboretums include gardeners, horticulturists, caretakers for the herbarium, staff members for preparing exhibits, directors of educational activities, editors and writers for the publication programs, librarians, research scientists, and many others. In some instances there are opportunities for travel to remote parts of the globe for the systematic exploration and collection of new (or old) plants. This may serve many purposes, such as adding to the collections, improving the exhibits, aiding in the preservation of plant species threatened with extinction, and discovering new species of value as ornamentals, as food plants, or as sources of new drugs.

If you wish to consider a career in this field, you should visit at least one botanical garden or arboretum, and preferably more than one, since they differ markedly in size, organization, and activities. Make an appointment with the director or other staff member, discuss your interests with him, and observe the place in action. If you don't know where there is such a garden near you, consult the volume *The Arboretums and Botanical Gardens of North America* by Donald Wyman, published by the Arnold Arboretum of Harvard University.

## ZOOS

What the botanical gardens do for plants, zoos do for animals. In addition, since animals have such fascination for people of all ages, attendance at zoos exceeds that at botanical gardens. In fact, no professional sport draws as many spectators as do the zoos. Zoos provide public recreation and outdoor amusement, but more importantly they are educational and research institutions. The educational activities of zoos include informative exhibits for the general public, the publication of guide books, tours for school children, orientation programs for school teachers (sometimes courses are given in cooperation with local colleges so that teachers may earn credit), public lectures and films, television programs, and facilities for the use of advanced students in the study of animal behavior. There are sometimes special programs for particular groups, such as clubs interested in birds or some other animal group, 4-H Clubs, Boy or Girl Scounts, photographers, artists, or others.

The importance of these activities varies with the size and resources of the zoo. They are carried on not only at the zoo, but there may be classroom follow-ups with zoological specimens taken to schools. The zoo employees most often encountered by the public are the groundsmen, keepers, and their assistants. Keepers are practical animal husbandmen; recently, there has been a tendency to elevate the positions professionally and to demand more training than in the past. Curators are the professional zoologists in the zoo, and positions as curators are often held by individuals with master's or Ph.D. degrees. Curators not only supervise the care of the animals, but make decisions on the choice of animals to display and the means used to present the displays to the public.

The zoologist in the zoo may perform research on animal breeding, genetics, ecology, animal behavior, or other topics. He or she may need to travel to visit other zoos, to study animals in their native state, or to collect specimens. Although the most familiar animals in the zoo may be the mammals, there must also be experts on birds (ornithologists), reptiles and amphibians (herepetologists), and fish (ichthyologists). An aquarium for the study and display of fish and other aquatic creatures is often associated with a zoo, but it may be separate. Workers at zoos and aquariums find that their work never gets dull, they are relatively free from bureaucratic regulations, and their salaries are comparable with those of people of corresponding education and responsibility in local schools and colleges.

## MUSEUMS OF NATURAL HISTORY

Most of us like to make collections of interesting objects, and the greatest collections of objects of scientific interest are in natural history museums. Museums play an important role in transmitting scientific information to the public, hence they are of increasing significance as informal educational institutions. The most visible evidence of the museum's educational function is the exhibit. Museum exhibition as a profession has a strong appeal to certain persons, but the employment opportunities are limited. Often, exhibits are prepared by staff members whose primary duties lie elsewhere, but there is an increasing tendency for museum exhibition to become a profession in its own right.

Exhibits are educational displays. Their preparation involves conception and planning followed by design and execution. The exhibitor, then, is less of a specialist than are most biologists. Not only must the person be well grounded in general biology, but he or she should especially understand systematics, ecology, and conservation. In addition, it is important to know something about the principles of three-dimensional design, color harmony, photography, and the like. The exhibit designer will have some contact with anthropology, paleontology, geology, and geography—he or she does not need to be an "expert" in these fields, but should have sufficient understanding of them to be able to collaborate with professionals in such disciplines. Dr. A. G. Wright, of the Museum of Natural History, Smithsonian Institution, has put it this way: "The professional practitioner of museum exhibition, as here envisaged, might be more accurately described as a generalist."

The exhibit is by no means the only educational medium of the natural history museum. Many museums contain classrooms, and museum personnel often collaborate with local school systems in informal instruction either in the museum of in the schools. The museum's collections are also important sources of material for instructional purposes or for scholarly research. The curator in a large natural history museum is generally a systematic biologist (see Chapter 4), and has duties which are manifold: he or she occasionally makes field trips to remote areas for specimens. Once the specimen is in the museum's collection, it has to be properly identified, documented, labeled, and maintained in condition for proper use by scholars not only now but in future generations. The curator also helps in the exhibit programs, collaborates with colleagues in other institutions, gives lectures—both technical and popular—and must do scholarly research

in the field and publish the results in technical journals. In many instances, the curator holds an appointment on a university faculty (some important museums are integral parts of universities) and aids in the instruction of advanced students, especially graduate students.

The organization of the staff of a large museum, such as the National Museum of Natural History, a part of the Smithsonian Institution in Washington, D.C., resembles that of a university. The areas of interest to biologists are divided into departments, such as the Department of Vertebrate Zoology, Department of Invertebrate Zoology, Department of Entomology, Department of Botany, and Department of Paleobiology. Within each department are divisions staffed by biologists of various ranks such as Curators, Associate Curators, Assistants, and so on, reminiscent of the academic ranks of Professor, Associate Professor and the like. Most museum directors regard their curatorial and exhibit staffs to be undermanned, and seek to recruit young trained personnel within the limits of their budgets. Museums have caught the popular imagination and are increasingly being supported by the general public. Much of this support, however, is in the form of volunteer unpaid work. Many of these volunteers are well educated retirees or others not needing full time paid jobs. In museums they work as docents (guides and lecturers), laboratory assistants, and in the field. Although the activities of these volunteers reduce the necessity for hiring full time employees, the increased interest in museums as exemplified by them helps to draw additional funds available for recruiting young people for full time employment.

Positions as assistants in natural history museums are available in limited numbers. They are generally filled by applicants who have bachelor's degrees with majors in biology. In former years, many museum assistants were eventually promoted to curatorial positions, even without additional formal education. With the increasing emphasis upon research in systematic biology, appointment or promotion to the title of Curator today goes only to those who have completed the training for the Ph.D. degree. Many museums have training programs for technicians, and the technical assistant may be able to obtain the formal education necessary for promotion.

The jobs available in museums do not compare in numbers with those in teaching, industry, or government research, but for the limited number who find employment in them, museums offer an enjoyable environment. There are few careers that instill greater dedication on the part of their devotees. If you are interested in pursuing further the possibilities of a

career in museum work, you should visit a museum near your home and talk with a curator, or you may write to one of the major museums, such as the American Museum of Natural History, New York NY 10024 or the National Museum of Natural History, Washington, DC 20560.

## VOLUNTEER SERVICES

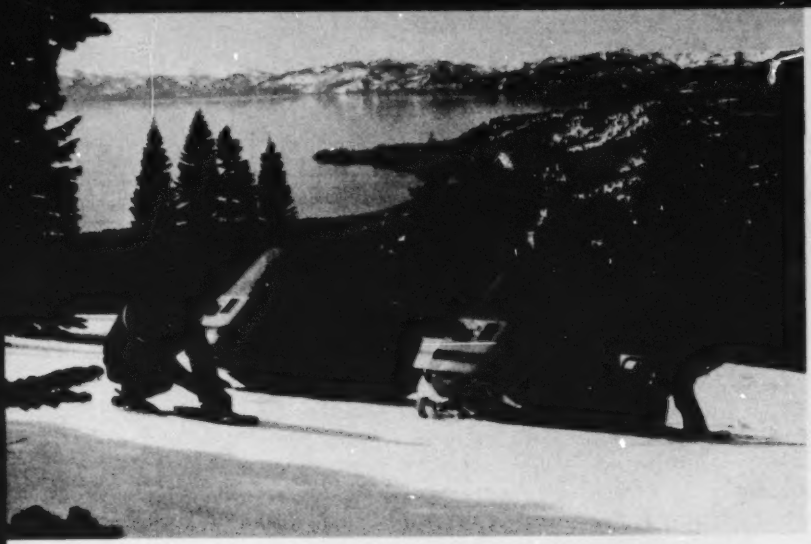
We should not leave the subject of nonprofit employers of biologists without a word about serving as a volunteer in areas where trained people are needed. You may not wish to serve in volunteer organizations as a permanent occupation, but a year or two spent in helping others may give valuable experience in addition to the satisfaction that comes from a useful job well done. There are many groups offering opportunities to be of service, and most of them do not specifically call for people with biological training. An exception is the Peace Corps, which has had many requests which can best be satisfied by individuals with biological knowledge. Peace Corps volunteers receive no salary, but transportation and health needs are cared for, and monthly allowances cover modest living costs.

The Peace Corps has dwindled in number since its highly visible days of the 1960s; but even in 1983 an estimated 5,200 volunteers were serving in 64 countries. As the economy improves, it is predicted that this number may increase. The Director, Loret Miller Ruppe, has particularly called for applicants with backgrounds in forestry, agriculture, and fisheries.

Biologically trained volunteers have served in many parts of the globe. Most of them have taught in secondary schools, in teacher training schools, or they have assisted in field work. Included among the fields of biology for which there have been calls in the past are:

- Training teachers in general biology, botany, bacteriology
- Medical technologists to train hospital technicians
- Help in fresh water fisheries and fish farming
- Assistance in livestock breeding
- Entomologists to aid in pest control
- Plant pathologists for help in controlling plant diseases

The overseas Peace Corps and the domestic ACTION program have been merged since the 1970s; information can be obtained by writing to ACTION—Peace Corps, Washington, DC 20525, or to the Smithsonian Institution, Washington, DC 20560.



In a biology career you may work in the high mountains, or in an urban laboratory—or you may work in a number of different environments, in the same job. Above, snow mobiles are used by snow surveyors at Lake Tahoe as part of the conservation program. Photo: USDA—Soil Conservation Services, photographer Donald C. Schuhart. Below, a pathology researcher examines heart tissue at Cedar Sinai Medical Center, Los Angeles. Photo by Gary Gilbert.

CHAPTER 8

# FINDING THAT JOB

You are about to enter the final phase of your training . . . or perhaps you are about to start training. In either case, you may want to know: How will I go about getting a job when I'm ready? What may I do in the way of preparation so that I will not wind up with an advanced degree in biochemistry and then discover that the only job I can find is pumping gas? The more you know about how biologists go about obtaining jobs, the better prepared you will be for locating a job when you are ready. There are, of course, employment agencies, who are in the job-finding business for profit. In any large metropolitan area, the Yellow Pages of the telephone book has several pages of employment agencies listed. Many of them are specialized and may not have the kinds of jobs you are interested in, but some of them have special departments for technically trained personnel. You may have your name listed in an agency, then when a job is located, the agency collects some agreed—upon portion of the first year's salary, usually paid by the employer.

Whether you are enrolled with an employment agency or not, you should not depend entirely upon that approach. For one thing, you should not be bashful about writing to any prospective employer. Indeed, some employers welcome a personal unsolicited approach; there are usually more unadvertised jobs than advertised ones, and some employers may be impressed by the aggressiveness shown by an unsolicited application. This will more likely be the case in small rather than very large organizations, where you might have to deal with the Personnel Department rather than with the individual having a job opening. It is important, of course, if you use the direct approach that your application be well prepared; you should obtain the help of your counselor.

## COLLEGE PLACEMENT BUREAUS

Many colleges have placement bureaus which assist their students and graduates in finding jobs. These may be especially useful in finding teaching positions. Companies often send recruiters to campuses for employment interviews. Although many of these recruiters are looking for graduate students about to complete their requirements for a doctorate, openings at a lower level are also sometimes available in these interviews. Companies with vacancies in their research laboratories or in other departments will sometimes ask a likely candidate to visit them at the company's expense. The candidate may be wined and dined and given the red carpet treatment if he or she has some special talent the company is looking for, but even a beginner can have an interview, not only with the campus recruiter, but often directly with the employer.

## PERIODICALS

Many professional, scientific, and trade journals have classified sections with advertisements for "Positions Wanted" and "Positions Open". Among these are such prestigious scientific journals as *Science, Nature, BioScience, Genetics,* and *Federation Proceedings, Federation of American Societies for Experimental Biology.* Others are special trade periodicals; among those in this category which announce jobs of biological interest are *American Dairy Review, American Fruit Grower, American Vegetable Grower, The Commercial Fish Farmer, Pulp and Paper, Wines and Vines,* and many others. Then there are those of regional interest, or those aiming their appeal to special groups, such as *California Farmer, Pacific Coast Nurseryman, Southern Florist and Nurseryman, The Black Collegian, Black Careers,* to name a few examples. The above are just a few selected examples. A more complete list—in fact, some 166 periodicals overall—is contained in the *Life Science Jobs Handbook* (see Appendix B). The list covers 23 different biological disciplines which have been the subjects of job announcements in these periodicals.

Besides these opportunities for full time jobs, there are often opportunities for young graduates to obtain graduate fellowships; these are frequently advertised in scientific journals. Not to be overlooked are the "Help Wanted" columns of major city newspapers. Some of these, such as the *New York Times, Washington Post,* and *Chicago Tribune,* carry ads of

more than local interest in their particular geographic area. Perhaps I should remind you, though, that a very popular job advertised in this way can draw many hundreds of responses, and this reduces the chances of any one applicant. It is clear, then, that in looking for a job one should not rely exclusively on such ads, but if you use them, they should be answered promptly, and you should scan the paper not just once, but with perseverance. Sometimes the information provided in an advertisement may give you a clue by which you may make the more direct approach described above; you may thus be able to locate an unadvertised position.

## PROFESSIONAL ASSOCIATIONS

Scientific societies take an interest in helping employers and prospective employees get together. This interest may be implemented in one or more of several different ways: by advertisements in the official journal of the society, by maintaining placement services in the society's office, or by arranging job interviews at the annual meeting of the organization.

Before going into this in more detail, perhaps it would be helpful to say something about scientific societies in general, and biological associations in particular. There is a great variety of them, and most professional biologists will find it to their advantage to belong to a society which expresses their particular interest; indeed, it is quite the usual thing for a bioscientist to belong to more than one. The societies serve important functions both social and in communications. Most of them publish official journals which help their readers keep up with developments in their field but also keep contact with each other. These functions are also aided by the meetings held on an annual basis, and sometimes more frequently.

Each specialty in bioscience boasts its own society—such organizations as American Association of Anatomists, American Society for Microbiology, Botanical Society of America, and so on. The societies also band together both on a national and an international scale. The qualifications for membership in the various societies vary widely; in some cases, it is only necessary for one to express an interest in the society and pay the dues; others admit to membership only those who have demonstrated ability to conduct and publish results of research in a particular field. Some have more than one category of membership, welcoming not only established professionals but also beginners, with special provision for students.

Science transcends international boundaries, so many of the national societies belong to International Unions, and these in turn into one grand overall organization called International Congress of Scientific Unions (ICSU). Their function is to promote meetings in which scientists of various nations get together and exchange information on their latest research findings. On a national scale, the *American Association for the Advancement of Science* (AAAS) includes scientists of all disciplines, including bioscience. In many states or other local areas there is also a local "Academy of Science". The AAAS is an association of many scientific societies, both physical and life sciences, but the individual scientist is also a member of AAAS, and indeed nonscientists or those not members of any constituent society are welcomed as members of AAAS. Annual meetings of AAAS give beginners an opportunity to meet established scientists and to obtain job interviews.

Associations of biological societies of special interest to biologists are the *American Institute of Biological Sciences* (AIBS) and the *Federation of American Societies for Experimental Biology* (FASEB). These two large associations are supplemented by societies which belong to no federation. FASEB is primarily of interest to those engaged in research in a biomedical science, as will become apparent if we just list the names of the constituent societies: The American Physiological Society, American Society of Biological Chemists, American Society for Pharmacology and Experimental Therapeutics, American Association of Pathologists, American Institute of Nutrition, The American Association of Immunologists. FASEB does not accept individuals as members, but one is a member of FASEB only by virtue of membership in one or more of the constituent societies. However, nonmembers, especially students, are welcome at meetings, they may present papers, and—most importantly for our present discussion—FASEB operates a Placement Bureau which maintains a list of employers with vacancies and those looking for jobs. The list is published annually. In addition, interviews are scheduled between employers and prospective employees.

The largest organization of biologists is AIBS. It is a federation of biological societies, but unlike FASEB it also accepts individual members. AIBS merits the support of all biologists, and indeed its goal is to enroll all professional biologists. AIBS has provided consulting services for many governmental agencies and private foundations; it has served such groups as the Environmental Protection Agency, National Science Foundation, Food and Drug Administration, and many others. AIBS keeps up to date

records of biographical and professional information concerning bioscientists and publishes periodicals which keep members and subscribers informed on current interests of biology and biological education.

The Education Department of AIBS is of special importance to students and teachers or to anyone contemplating a biological career. This department is actively engaged in career guidance, and handles many thousands of requests for career information. These requests come from students, faculty, guidance counselors, and others. The office has sponsored and guided bioscience curriculum studies which have largely revolutionized the teaching of biology in high schools and colleges. Its activities include the preparation and updating of a brochure, *Careers in Biology,* as well as aiding in the dissemination of career booklets prepared by the individual societies which make up the AIBS. AIBS also charters student chapters in high schools and colleges throughout the country. Participation in a student chapter provides an opportunity for students to maintain contact with biologists and biology students all over the country and to gain insight into what biology as a profession is all about.

AIBS maintains a placement service which supplies lists to candidates and to employers so that they can meet by correspondence, or can meet for personal interviews at the annual convention. Each year, many biologists, especially beginners, get to meet prospective employers this way. Either FASEB or AIBS will be glad to answer any questions regarding careers or employment at these addresses: FASEB Placement Service, 9650 Rockville Pike, Bethesda, Maryland 20014; Education Department AIBS, 1401 Wilson Boulevard, Arlington, Virginia 22209.

## PERSONAL CONTACT

As you can see, there are many different ways for a biologist to look for a job. Perhaps the most important of all is personal contact. This is especially true as one advances in the profession. During the early stages of a biologist's career, as the student is about to graduate from college, the professors with whom one has been studying will have received notices of fellowships, graduate assistantship, and various teaching, service, or research jobs available to graduates. In many departments, such notices are regularly posted on the bulletin boards; there will also be some on the professors' desks. Some of these vacancies will be available to those just completing study for a baccalaureate degree, others will be for those about

to receive the doctorate. In either case, there is a good chance that one's professor is personally acquainted with the prospective employer. In that case, it is more than likely that the personal recommendation of the professor will carry more weight with the employer than any other single document or record the candidate can produce.

The department head who has a vacancy on the staff for a young person will not only write to the schools which operate training programs, but when going to a convention of scientists will inquire of friends, "Do you know a good man or woman whom I can get to fill this position?" At the larger scientific meetings, the corridors are filled with people on the alert for job opportunities, and often with others seeking applicants. If you are one of those looking for a job—or if you already have one but think there might be something better—you will find that as your experience and reputation grow, you will be more and more likely to be one of those sought by employers. Biologists are not a restless lot, but there is some ebb and flow of people among jobs.

After you become known to other biologists as someone whose work merits attention, you may be given chances at more jobs than you can ever fill. When that happy day arrives, the attention paid to you by prospective employers not only gives a lift to your ego, but in many cases opens the eyes of your present boss to your true worth so that you are rewarded with a raise and a promotion to keep you from moving. Then you might join that large group of scientists who like their location so much that they spend practically their entire working lives on one campus or in one laboratory.

## APPENDIX A
# GLOSSARY

**AAAS.** The American Association for the Advancement of Science.

**Agricultural Science.** Any of several applied biological sciences seeking to discover knowledge about plants and animals and apply the discoveries to the needs of mankind for food or fiber.

**Agronomy.** Scientific agriculture; the application of plant sciences and soil science to the raising of crops and management of soil.

**AIBS.** The American Institute of Biological Sciences.

**Algology.** A branch of systematic botany dealing with the algae, simple green plants comprising the seaweeds and similar forms of fresh water and damp places.

**Anatomy.** The biological science dealing with the structure of a plant or an animal; used more or less interchangeably with the word *morphology*.

**Animal Science.** A term often used more or less synonymously with *animal husbandry;* the branch of applied biology relating to the breeding, nutrition, physiology, and diseases of domestic animals, especially those of importance to agriculture.

**Aquaculture.** The practical application of biological knowledge to the cultivation of the growth of organisms, usually fish, oysters, or shrimp, in water; analagous to agriculture on land; if sea water is involved, it is often called *mariculture*.

**Aquatic Biology.** Biological science, either basic or applied, concerned with biological events or organisms in water; if sea water is involved, it is usually called *marine biology* and may be considered to be a branch of *oceanography;* as sometimes used, the term *aquatic biology* refers to fresh water and is a branch of *limnology*.

**Bacteriology.** The scientific study of the bacteria; a branch of *microbiology*.

**Biochemistry.** The scientific study of the chemistry of living things; the study of living matter or of substances derived from living matter whether plant, animal, or microorganism, by the use of the methods of chemistry. Synonyms: *biological chemistry, physiological chemistry*.

**Biology.** A broad and all-inclusive term for any scientific study of life; all the sciences discussed in this book are branches of biology.
**Bionics.** The application of biological principles to the study and design of engineering systems.
**Bionomics.** see *ecology*.
**Biophysics.** A branch of biology which uses the tools and concepts of physics to study living matter.
**Biosystematics.** The branch of biology dealing with the description, classification, and naming of plants and animals (see *taxonomy*), together with whatever features distinguish one species from another, whether anatomical, biochemical, ecological, etc. and any information enabling the bioscientist to place an organism in its place in the evolutionary process; also called *systematics* or *systematic biology*.
**Biotechnology.** The application of biological principles to practical objectives, especially as illustrated by such procedures as genetic engineering, cell fusion, embryo transfer, and other highly technical manipulations.
**Botany.** The scientific study of plants; a general term including many biological disciplines, as applied to plants.
**Bryology.** A branch of systematic botany concerned with mosses and liverworts.
**Cytology.** The scientific study of cells, including structure, formation, biochemistry, and functions.
**Dendrology.** The branch of botany concerned with trees and shrubs.
**Ecology.** The scientific study of the relationship of an organism—plant, animal, or human—to its environment; sometimes called *bionomics*.
**Embryology.** The study of organisms in their earliest stages of development; in zoology, before hatching (oviparous animals) or in rudimentary beginning stages (viviparous animals); in botany, the rudimentary plant contained in the seed.
**Endocrinology.** A branch of physiology concerned with the endocrine glands or other structures which release substances exerting physiological effects at sites other than their points of origin.
**Entomology.** The scientific study of insects.
**Ethology.** The study of animal behavior by observing normal activities; for example, the imitation by a member of a species of the actions of others (original meaning: the portrayal of character by mimicry).
**Evolution.** The changes in inherited characteristics of a species so that descendents may differ morphologically or physiologically from their ancestors.
**FASEB.** The Federation of American Societies for Experimental Biology.
**Forestry.** The branch of applied science concerned with all aspects of the planting and care of forest trees.
**Genetic engineering.** The alteration of genetic material by chemical or

physical means to produce an intentional change in inherited characters.

**Genetics.** The science of heredity; concerned with all aspects of the biological processes involved in inheritance, or the passing on of characteristics from one generation to the next.

**Gnotobiotics.** A branch of biology dealing with breeding and growing animals in a germ-free environment.

**Hematology.** The study of blood, including both cellular and fluid parts.

**Herpetology.** A branch of systematic zoology dealing with reptiles and amphibians.

**Histology.** A study of the microscopic structure of the tissues of plant or animal.

**Horticulture.** A study of the cultivation of garden plants.

**Hybridoma.** An artificial organism or new type of cell formed by fusion of two different types of cells.

**Ichthyology.** A branch of systematic zoology dealing with fishes.

**ICSU.** The International Congress of Scientific Unions.

**Immunology.** The scientific study of the bodily processes involved in immunity to disease and similar biochemical reactions.

**Limnology.** The scientific study of bodies of freshwater; includes physical, geographic, and other aspects as well as biological; the corresponding study of the ocean is *oceanography*.

**Mammology.** The branch of zoology dealing with mammals, animals that suckle their young.

**Mariculture.** See *aquaculture*.

**Marine Biology.** See *aquatic biology*.

**Microbiology.** The scientific study of microscopic organisms.

**Morphology.** The study of the structure of an organism without regard to function; same as *anatomy*.

**Mycology.** A branch of systematic botany dealing with fungi; that is, yeasts, molds, and mushrooms.

**NABT.** The National Association of Biology Teachers.

**Oceanography.** The scientific study of the oceans.

**Organism.** Any living form, whether an animal, a plant, a bacterium, or other.

**Ornithology.** A branch of systematic zoology dealing with birds.

**Parasitology.** The scientific study of parasites; that is, of plants or animals which obtain their nutriment by living in or upon other living bodies.

**Pathology.** The scientific study of disease, including its origin, nature, and effects upon the body.

**Pharmacology.** The scientific study of the effects of foreign chemical substances upon bodily functions; the study of drugs and their effects on the body.

**Physiology.** The scientific study of functions of living organisms or of any of their parts.

**Phytopathology.** The study of the diseases of plants.

**Plankton.** Small plants (phytoplankton) or animals (zooplankton) that float or drift about in the water, especially those near the surface; plankton are at the bottom of the food pyramid—they are eaten by larger creatures.

**Plant Pathology.** See *phytopathology.*

**Plant Physiology.** The study of functions of plant organisms or of any of their parts.

**Protozoology.** The scientific study of one-celled animals.

**Rickettsia.** Bacteria-like organisms living as parasites in ticks, etc., causing certain diseases, such as Rocky Mountain spotted fever; Rickettsiae are microorganisms differing in certain details from bacteria or viruses.

**Systematics; Systematic Biology.** See *biosystematics.*

**Taxonomy.** Description, classification, and naming of organisms, an integral part of biosystematics.

**Technician.** In the biology laboratory, a technician is a laboratory worker who is skilled in the art and technique of biology and is a valuable assistant to the professional scientist in charge of the laboratory, and who may supervise other technicians, but who lacks the theoretical background or experience to have full charge of complex operations such as research projects.

**Technologist.** A technician; as commonly used, a technologist may have a higher degree of formal training than a technician (as these terms are officially employed by the American Society of Clinical Pathologists, for example).

**Toxicology.** The scientific study of poisons, their detection, effects, and antidotes—a branch of pharmacology.

**Virology.** The study of viruses and of the diseases caused by them.

**Virus.** An infectious agent requiring living cells for propagation; viruses are smaller than bacteria.

**Zoology.** The scientific study of animals; a general term including many biological disciplines as applied to animals.

**Zoonosis.** A disease of animals transmissable to humans; plural, zoonoses.

## APPENDIX B

# SELECTED SOURCES OF FURTHER INFORMATION

## GENERAL

Note: Many of the sources listed below contain further references.

*American Institute of Biological Sciences,* 1401 Wilson Boulevard, Arlington, Virginia 22209. AIBS publishes career information in the form of a brochure *Careers in Biology,* which is revised from time to time, also the *AIBS Directory of Bioscience Departments and Faculties of the United States and Canada.* Inquiries about careers in biology may be addressed to the AIBS *Education Department,* which answers many individual requests; this office also has available for distribution career brochures of several of the constituent societies of the AIBS.

*National Association of Biology Teachers,* 11250 Roger Bacon Drive, Reston, Virginia 22090, publishes career information from time to time in their official journal, *The American Biology Teacher;* for example, two entire issues, March and April, 1978, were given over to discussions of careers in biology.

*U.S. Department of Labor, Bureau of Labor Statistics,* Washington, D.C. 20025, publishes several periodicals, including *Occupational Outlook Handbook, Occupational Outlook Quarterly,* and *Exploring Careers;* many libraries have updated copies of these reports, or they may be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

*Life Sciences Jobs Handbook,* R. B. Uleck Associates, Box 3069 Diamond Farms Branch, Gaithersburg, Maryland 20760 lists many different kinds of biologically oriented careers, periodicals where job information can

be obtained, information on job placement services, government agencies, names and addresses of employers, and where further information can be obtained.

*American Association for the Advancement of Science,* 1515 Massachusetts Ave., N.W., Washington, D.C. 20005: *Careers in Science* and *Careers in Teaching.*

*Smithsonian Institution,* Washington, D.C. 20560, also answers inquiries about career opportunities, and sometimes issues lists of *Sources of Information on Careers in Biology, Conservation, and Oceanography.*

*National Science Foundation,* 1800 G St. N.W., Washington, D.C. 20550, publishes *Science and Engineering Education: Data and Information;* the NSF Division of Science Resource Studies frequently updates a "Highlights" report on educational statistics.

Lists of colleges and universities offering educational opportunities in the biological sciences, in addition to the AIBS Directory mentioned above, include the following:

*Lovejoy's College Guide,* Simon and Schuster, 630 5th Ave., New York, N.Y. 10020

*The College Blue Book,* Macmillan Publishing Co., 886 3rd Ave., New York, N.Y. 10022

*Barron's Profiles of American Colleges,* Barron's Educational Series, Inc., Woodbury, N.Y. 11797

*Internships — on-the-job training opportunities — Writer's Digest Books, Cincinnati, Ohio 45242*

*Index of Majors,* College Entrance Examination Board, Box 886, New York, N.Y. 10101

*VGM Career Horizons, Division of National Textbook Co.,* 4255 W. Touhy Ave., Lincolnwood, Illinois 60646, publishes a large series of books on vocational guidance; titles on topics related to biological sciences (in addition to this book) include:

*Opportunities in Environmental Careers,* by Odom Fanning
*Opportunities in Forestry,* by Christopher M. Wille
*Opportunities in Paramedical Careers,* by Alex Cacen
*Opportunities in Pharmacy Careers,* by Fred B. Gable

## WOMEN AND MINORITIES

*Women in Science,* by Alice Fins, VGM Career Horizons (address above) contains biographies of women scientists and details of where further information can be obtained of interest to women

Professional periodicals often publish articles on women and minorities; for example: *Wanted: More Women in Science,* by Mary Jo Boehm Strauss, in *The American Biology Teacher,* vol. 40, pp 181-188, 1978; *Women in Science,* by Jonathan R. Cole, in *American Scientist,* vol. 69, pp 385-391, 1981

*The Black Collegian* publishes career articles from time to time; for example, a series on *Careers of the Future* appeared in the issue of August/September 1982, and another series *Biology Careers are Alive and Well* in October/Novemer 1982

Career information of special interest to black students also appears in *Black Careers — Project Magazine, Inc.,* P.O. Box 8214, Philadelphia, PA 19101, and *The Black Scholar, Black World Foundation,* P.O. Box 908, Sausalito, CA 94965

*Women's Work,* bimonthly; Suite 203, 1302 18th St. NW, Washington, D.C. 20036, publishes many articles of interest to women seeking careers

## FINANCIAL ASSISTANCE

Many of the above publications contain information on financial assistance for students; in addition, there are a few specifically directed toward this important subject:

*Bureau of Student Financial Assistance,* P.O. Box 84, Washington, D.C. 20044

*Scholarships, Fellowships and Loans,* by S. Norman Feingold and Marie Feingold, Bellman Publishing Co., P.O. Box 164, Arlington, Massachusetts 02174

*Annual Register of Grant Support,* Marquis Professional Publications, Marquis Who's Who, Inc., 200 E. Ohio St., Chicago, Illinois 60611

Information on financial assistance can also be obtained directly from the school or college, or from your state's department of education

## BIOLOGICAL SPECIALTIES

Many of the biology societies publish career brochures which are revised from time to time; a list of the professional societies and their addresses is in the *Life Sciences Jobs Handbook,* mentioned above. The AIBS brochure *Careers in Biology* lists the career information published by the individual societies which make up the AIBS; some of these can be obtained direct from the AIBS office at 1401 Wilson Blvd., Arlington,

Virginia 22209. Here are a few examples of career brochures published by biological societies:

*Consider Entomology,* Entomological Society of America, 4603 Calvert Road, College Park, Maryland 20740.

*Careers in Industrial Microbiology,* Society for Industrial Microbiology, brochure obtainable from AIBS

*Animal Sciences and You — the Right Career Combination,* American Society of Animal Science, 309 Clark St., Champaign, Illinois 61820

*Careers in Mycology,* Mycological Society of America, Dr. Melvin S. Fuller, Department of Botany, University of Georgia, Athens, Georgia 30602

*Fisheries as a Profession,* American Fisheries Society, 5410 Grosvenor Lane, Bethesda, Maryland 20014

*The Science of Mammology,* The American Society of Mammologists, c/o The Vertebrate Muséum, Shippensburg State College, Shippensburg, Pennsylvania 17267

*Your Career in Ecology, Ecological Society of America, Department of Botany and Microbiology, Arizona State University, Tempe, Arizona 85281*

*Careers in Biological Systematics,* Society of Systematic Zoology, or American Society of Plant Taxonomists — both located at Smithsonian Institution, Washington, D.C. 20560

Some of the career brochures published by biological societies do not show the date of publication, and some are revised rather infrequently. Furthermore, the addresses of some change from time to time. The societies which adhere to the Federation of American Societies for Experimental Biology do maintain permanent offices at 9650 Rockville Pike, Bethesda, Maryland 20814, and career information can be obtained by writing either to the Executive Officer of the Federation at that address, or to the Executive Officer of any of the individual societies; the societies which form the Federation are:

The American Physiological Society
American Society of Biological Chemists
American Society for Pharmacology and Experimental Therapeutics
American Association of Pathologists
American Institute of Nutrition
The American Association of Immunologists

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Dance
Dental Care
Drafting
Data Processing
Electrical Trades
Electronic and Electrical Engineering
Energy Careers
Engineering Technology
Environmental Careers
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Film
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Food Services
Foreign Language Careers
Forestry
Free Lance Writing
Government Service
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Hospital Administration
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Law Careers
Law Enforcement
Library and Information Science
Machine Shop Trades
Magazine Publishing
Management
Marine & Maritime
Materials Science
Mechanical Engineering
Nursing
Occupational Therapy
Office Occupations
Opticianry
Optometry
Packaging Science
Paralegal Careers
Paramedical Careers
Personnel Management
Pharmacy
Photography
Physical Therapy
Podiatric Medicine
Psychiatry
Psychology
Public Relations
Real Estate
Recreation and Leisure
Refrigeration and Air Conditioning
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Here is everything you need to explore a career in this unique field! Written by a leading authority, this comprehensive guide gives all the information you need for *intelligent* career decision making. Among its many features are

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- employment outlook
- career advancement
- educational requirements
- salary opportunities
- where to get more information

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